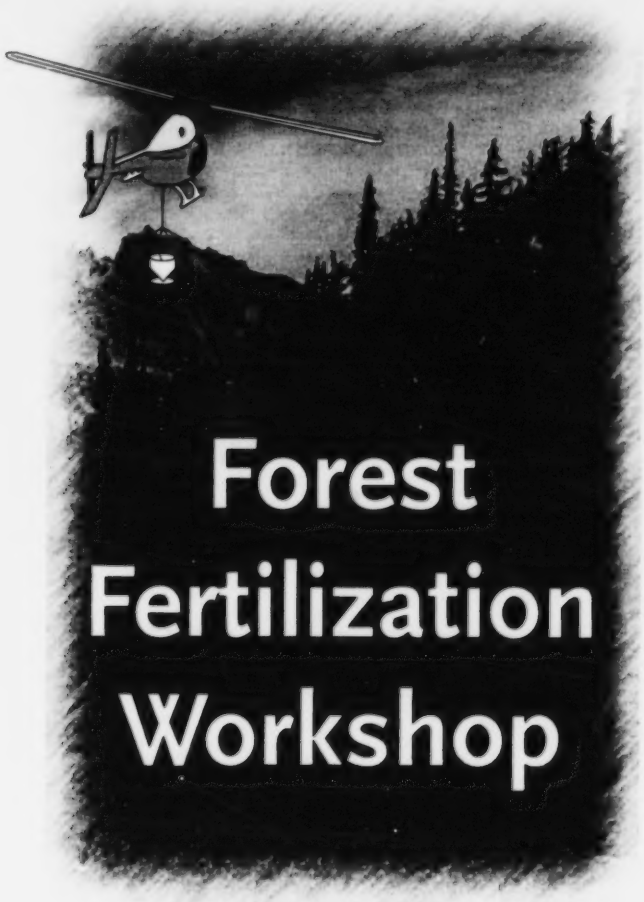

Forest Fertilization Workshop

Modular Based Training

Facilitator's Guide

FOREST RENEWAL BC

BRITISH COLUMBIA

Ministry of Forests
Forest Practices Branch

106-0 5785 /

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Appendix

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Instructions to the Facilitator

How to Use this Guide

You have been contracted to communicate the information included in this facilitator's guide to workshop participants. You must have the approval of the Ministry of Forests contact person before adding information or changing any portions of the intended message of this workshop.

The success of any workshop will depend on how well the facilitator selects activities to communicate the intended message to the participants. This guide is a complete package and should address the needs of most audiences. However, the care and thoroughness with which you plan and prepare for each workshop will make the difference between a mediocre and a successful event. Please review these materials carefully and enjoy your role in the learning process.

This guide is designed to help you prepare for and deliver this workshop.

The Workshop Introduction contains general information on the background, objectives, target audience and format for the workshop. Please read this information to ensure that you understand why and how this workshop was developed.

Lesson plans at the beginning of each lesson provide learning objectives, suggested delivery techniques and specific equipment and material requirements that you will have to coordinate. Each lesson contains explanatory information and copies of required overhead transparencies.

The participant's workbook has been created from the facilitator's guide. You should also review the workbook and become familiar with that material and the way in which it is presented.

Workshop Introduction

Purpose

The main purpose of this workshop is to provide participants with an overview of planning and operations for forest fertilization programs and projects through clarification of the use, intent and requirements of the *Forest Fertilization Guidebook* and the associated legislation and regulations under the Forest Practices Code.

Specific Learning Objectives

Participants will:

- be introduced to the concepts and principles of forest fertilization
- learn the strategic purposes of forest fertilization
- review the basic conditions for using forest fertilization as an appropriate forest management tool
- learn to select, evaluate and rank stands for fertilization
- gain the information needed to collect samples for an analysis of foliar nutrient concentrations
- learn the main points of forest fertilization contract administration
- investigate the requirements for the operation, implementation and monitoring of forest fertilization, as outlined in the Forest Practices Code
- understand the correct and safe manner with which to apply fertilizer and monitor its effects.

Target Audience

This workshop will be of interest and use to industry, government and consulting personnel responsible for preparing, implementing or monitoring prescriptions and contracts for fertilization.

Format

This forest fertilization workshop consists of ten lessons and is divided into two main sessions to separately address program planning and operations. Each session will require approximately a half day. This workshop has been designed to cover one day but it could be expanded, where required, to two days during the field season for an audience with advanced needs for program and operations details. The facilitator's guide and participant's workbook include appendices of useful reference documents that provide an expanded foundation for program planning and project operations. The review and discussion of the appendices could be combined with a half-day field trip to view active operations, monitoring methods or treated stands showing fertilization response.

The program planning session presents workshop participants with an overview for planning and prescribing fertilization, in relation to the

Forest Practices Code, at the forest estate and stand levels. The second session covers the operational aspects of a forest fertilization program – operation, implementation and monitoring. The purpose is to explain the important points of the Forest Practices Code *Forest Fertilization Guidebook* that pertain to the successful and correct operation, implementation and monitoring of a fertilization program.

Depending on the backgrounds and information needs of the participants, you, as the facilitator, may wish to minimize or even eliminate some of the lessons in the guide in order to concentrate on more relevant sections of the course to better meet the participants' needs. The time allotments for each lesson are suggestions for covering the entire *Forest Fertilization* course in seven hours. Note that the appendices include useful background information that has significant value for the participants, either as part of the workshop or as reference material for later use.

The video, *Forest Fertilization in British Columbia* is best used throughout the course as a supplement to the lecturettes and group discussion. The facilitator should decide whether to show the relevant portion of the video at the beginning of the lesson or as a summary at the end. In general, if the participants' experience is low or minimal, it is best to use the video as an introduction to the lesson. If the participants have a higher level of experience, the video can be used as a lesson summary or even skipped altogether if time is running short. The use of a video, however, gives the facilitator a short break and presents information in a refreshing form for the participants.

Various instructional techniques can be used to achieved the workshop objectives, including:

- lecturettes
- *Forest Fertilization* video
- case studies
- group exercises
- class discussion.

Participant involvement throughout the workshop should be the focus. The role of the facilitator is to direct discussions and clarify points. Maintaining tight control over time during the exercises is an important task.

Materials

Materials included with this guide include:

- overhead transparencies for all lessons
- *Forest Fertilization in British Columbia* video
- participant's workbook, including *Forest Fertilization Guidebook*
- references.

The workshop is designed for a maximum of 20–24 participants per course. Including more participants may make the group difficult to manage and will reduce the value of the learning experience for everyone.

Facilitators

This workshop is designed to be delivered by one facilitator, who should be very familiar with the subject matter.

Instructions

Read through all of the materials in the facilitator's guide carefully and ensure that you are comfortable with the flow and the materials for all the workshop exercises. If you have any questions, please ask the Ministry of Forests contact person.

You should also review the following references:

- *Forest Fertilization Guidebook*, September 1995, Ministry of Forests
- *Forest Fertilization in British Columbia* video
- Technical references included with facilitator's guide
- *Biosolids ... An Opportunity for Growth* video.

Workshop Overview

15 minutes

Objectives

- Provide an overview of the course and the timetable for the day
- Gauge the level of participant experience with fertilization for appropriate delivery of the workshop's lessons
- Solicit any questions regarding the workshop
- Help the participants feel comfortable with their workshop surroundings and the issues of the day

Equipment Needs

- Name tags
- Overhead projector
- Lesson 1 transparencies
- Participant workbooks
- Flip chart, wide-tip felt pens and masking tape

Method

Lecturette with group participation

Agenda

Session	Lesson	Time
	Registration	8:00–8:30
Introduction	Workshop Overview	8:30–8:45
	Introduction to Forest Fertilization	8:45–9:30
Program Planning	Forest Fertilization Program	9:30–10:15
	Break	10:15–10:30
	Biological Factors	10:30–11:10
	Operational Factors	11:10–11:30
	Stand Selection	11:30–Noon
	Lunch	Noon–1:00
Operations	Foliar Analysis	1:00–1:40
	Contract Administration	1:40–2:15
	Operational Fertilization	2:15–3:15
	Break	3:15–3:30
	Monitoring Programs	3:30–4:00
	Questions and Wrap-Up	4:00–4:30

Workshop Outline

Introduce yourself as the facilitator and your relationship to the workshop. If you have had experience with some aspect of the fertilization program, include that as well.

- Have the participants introduce themselves or their neighbour. Ask them to include their background regarding forest fertilization (i.e., whether completely new to it or have been involved in operations, etc.). Check them off the attendance list and ensure they have made name tags.
- Review the workbook briefly and its contents.
- Record any concerns or questions on the flip chart to ensure coverage in the workshop and post the flip chart page on the wall.
- Review the structure and layout of the participant's workbook.

Workshop Objectives

- Introduction
- Strategic purpose
- Basic conditions
- Stand selection, evaluation and ranking
- Fertilization plans
- Foliar analysis
- Contract administration
- Forest Practices Code
- Operations
- Correct and safe application and monitoring

Overhead: Workshop Objectives

Key Points

Participants will:

- Be introduced to the concepts and principles of forest fertilization
- Learn the strategic purposes of forest fertilization
- Review the basic conditions for using forest fertilization as an appropriate forest management tool
- Learn to select, evaluate and rank stands for fertilization
- Gain the information needed to collect samples for an analysis of foliar nutrient concentrations
- Learn the main points of forest fertilization contract administration
- Investigate the requirements for the operation, implementation and monitoring of forest fertilization, as outlined in the Forest Practices Code and the *Forest Fertilization in BC* video.
- Understand the correct and safe manner with which to apply fertilizer and monitor its effects

Lesson 2

Introduction to Forest Fertilization

45 minutes

Objectives

- Understand "Why fertilize?"
- Review the principles of forest nutrition and forest fertilization
- Introduce the main biological factors associated with a positive growth response to fertilization
- Demonstrate examples of stand responses to fertilization for the British Columbia coast and interior
- Review the legislative requirements regarding fertilization

Equipment Needs

- Overhead projector
- Lesson 2 transparencies
- Flip chart, wide-tip felt pens and masking tape

Method

Lecturette and class discussion with overheads

Instructions

The key points for the lesson are:

- Nutrition is only one of many factors controlling site productivity
- Fertilizer cannot replace the soil, where the complex processes of cycling nutrients in the ecosystem occur, following site degradation
- The potential to eliminate non-nutritional limiting factors may provide opportunities for fertilization treatments
- The combination of two plant physiological factors – increased foliar efficiency and foliar biomass – produces increased stem growth following fertilization
- Two Forest Practices Code regulations (Operational Planning Regulation and Silviculture Practices Regulation) provide the framework for fertilization planning and operations

Group Exercise

"Why Fertilize?"

Break up the participants into groups of two, and ask them to think of reasons to fertilize stands. Give them five minutes for this task then reconvene as a single group and list the reasons on the flip chart. Encourage group discussion and try to get each participant to provide input. Participants may have some reasons *not* to fertilize which should not be discouraged by the facilitator but listed separately on a separate flip chart page.

Post the flip chart pages on a wall where they are in good view for participants through the remainder of the workshop.

Points for Facilitator

"Why Fertilize?"

- Increase tree growth
- Increase vigour of forage species
- Reduce green-up time
- Increase conifer height growth on sites with high brush competition (e.g., salal) – may reduce risk of brushing treatment later to reach free growing stage
- Mitigate projected timber supply shortfalls
- Reduce rotation to achieve the planned stand diameter and volume
- Increase piece size and merchantable volume if rotation not reduced
- Optimize benefit of density control from juvenile spacing
- Optimize benefit from pruning treatment to produce clear wood

Growth Response to Fertilization

N → N

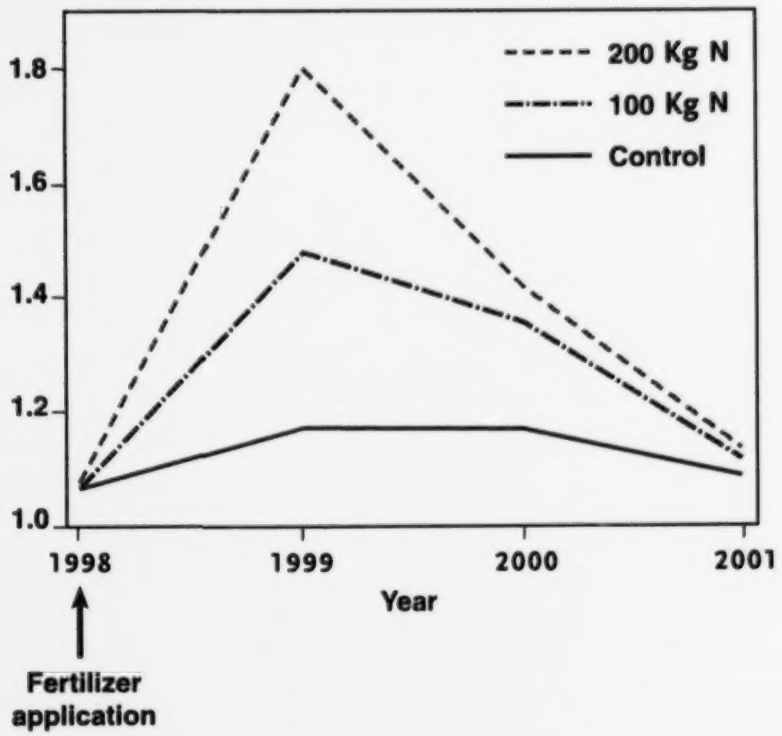
Mineralized 2–3%

Overhead: Growth Response to Fertilization

Key Points

- Fertilization adds only a small relative component of nutrients to the site and cannot significantly compensate for degraded soil
- Response depends on amount of added fertilizer taken up and stored in tree tissues and on tree species
- Mineralization is the process by which organic nitrogen is converted to ammonium nitrate, which the tree can use through root uptake. The opposite of mineralization is immobilization, in which NH_4^+ becomes organic and unavailable for uptake.
- Mineralization rate is usually only 2–3% annually of the site's total N pool
- N has to be inorganic for uptake

Foliar Nitrogen

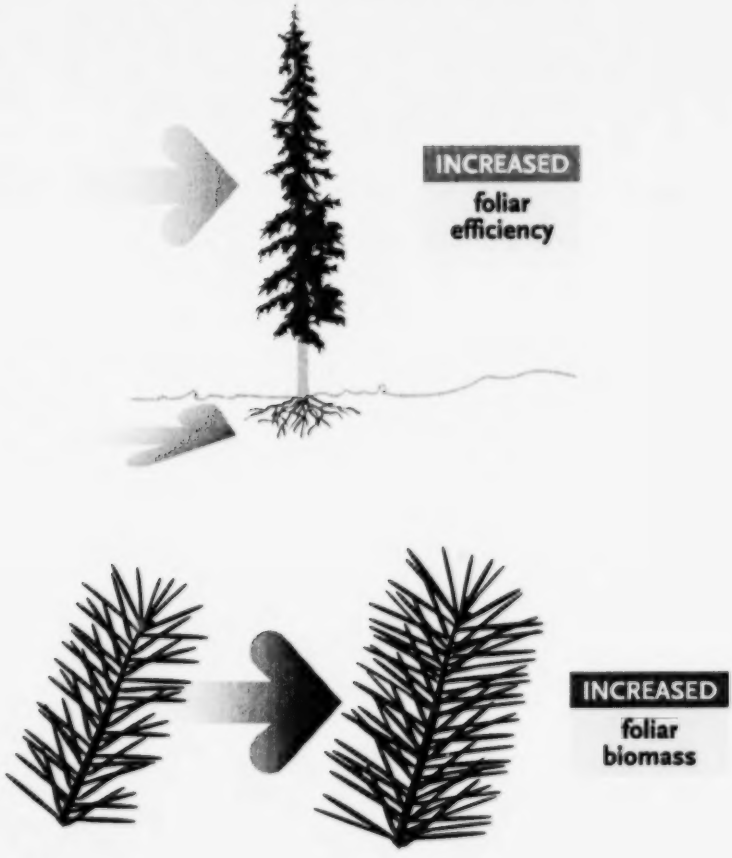


Overhead: Foliar Nitrogen

Key Points

- Differences in foliar nitrogen for different application rates
- Sharp drop off in foliar nitrogen the first year after fertilization, especially for the operationally used application rate of 200 kg N (i.e., short duration of response)

Response to Fertilization

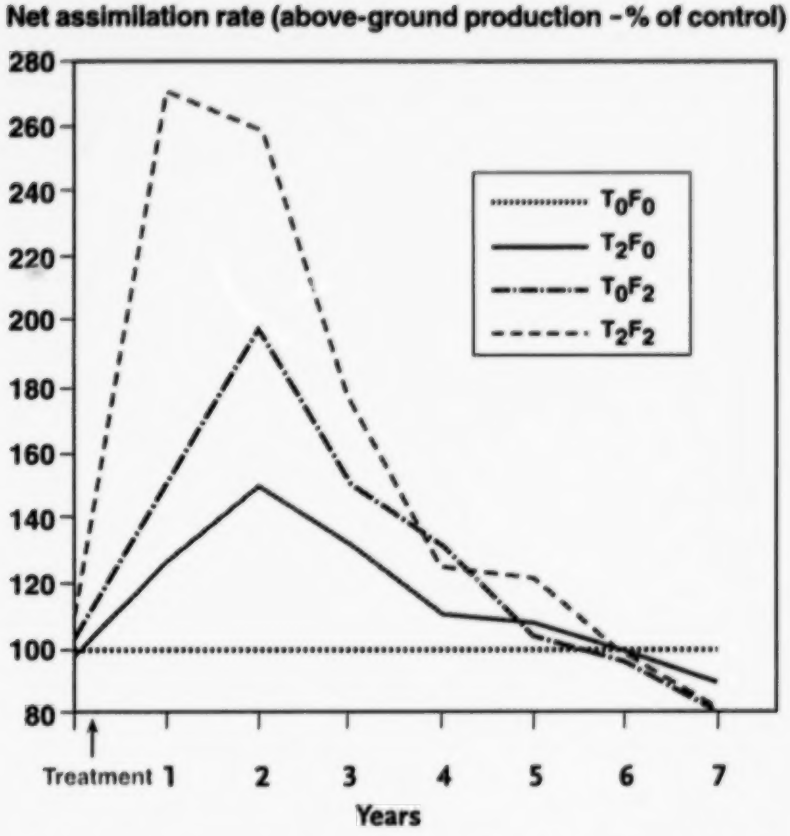


Overhead: Response to Fertilization

Key Points

- There are two factors following fertilization that increase tree (stem diameter) growth:
  - The tree's photosynthetic rate is improved, which allows the tree to reallocate biomass from fine root growth to stem wood growth
  - Fertilization also increases the number and weight of needles and their lifespan on the tree, which increases the tree's photosynthetic surface area and thus the "factory" for wood production

Net Assimilation Rates



Net assimilation rates by years based on total above-ground dry matter production.

* **Rates with thinning and fertilizer treatments are expressed as % of rate for control.**

Overhead: Net Assimilation Rates

Key Points

- Difference in treatments – point out on overhead graph and explain the treatment types (combinations of thinning and fertilization: 0 = no treatment, 2 = highest level of treatment)
- Ask the participants if they can explain the differences
- Note that all treatments drop below the control seven years after treatment – ***why?*** This is because these are **net** assimilation rates. The gross fertilization rates for the fertilized stands are still probably higher than the control but the fertilized stands' older needles are more for respiration now which increases the relative demand on the site. This higher demand is due to the increased foliage from the fertilization treatment. The lower net assimilation rate compared to the control is more common on drier sites that are moisture deficient, not nutrient deficient.

Foliar Biomass Increases

Foliar biomass increases five years post-treatment (adapted from Brix, 1981)

	Treatments			
	Control	Thinned	Fertilized	Thinned and Fertilized
Total # of needles	21 000	30 600	60 100	58 300
# of shoots	269	326	572	750
Needles/shoot	78	94	105	91
Ave. shoot length (cm)	4.58	4.81	5.76	5.12
Needle density (#/cm)	16.3	18.8	17.1	16.7
Total needle weight (g)	82.8	132.0	247.3	305.0
1000 needle weight (g)	3.95	4.31	4.11	4.47

Overhead: Foliar Biomass Increases

Group Exercise

Display Overhead 2–5 on overhead projector (also available in participant's workbook) and ask the participants to look for trends in the data based on the treatment(s) and the change in foliar biomass five years after treatment. Give them 3–5 minutes to think about this and jot down their observations in their workbook.

Key Points

- Data are for Douglas-fir from Shawnigan Lake research trial on Vancouver Island
- Ask the participants what they notice from these data. Why would these results be happening, based on the treatments and the associated stand responses?
- Thinning increases most variables over the control (untreated) by up to 50%
- Fertilization increases the results further, and thinning and fertilization produce an even further increase
- Are there any anomalies in the data? ***Any possible explanations?***

Explanation of Trends

The total number of needles and number of shoots increased from thinning, then almost doubled further after fertilization. The third treatment regime, thinning and fertilization combined, created a further increase in these measurements. This resulted from the ability of the crowns to expand after thinning using the nutrient boost from fertilization. Each tree became a better "factory" for growing wood through improved photosynthetic capacity. This is one of the key responses from fertilization and it demonstrates the critical need for ample space for crown expansion to realize the potential fertilization effect.

The number of needles per shoot, average shoot length and needle density decrease from fertilized or fertilized only to thinned and fertilized. This is due to the results of the above measurements. With crown expansion from the increased number of shoots and needles, the tree has become more efficient, especially from the combined thinning and fertilization treatments. The total needle weight and 1000 needle weight show that the thinned and fertilized trees have heavier needles. The middle three measurements must be regarded in the context of changes to the tree from the two silviculture treatments.

When a tree has been growing in a suppressed or intermediate canopy position, it adapts to the low light levels by growing shade needles. Shade needles minimize respiration and are able to maximize photosynthesis in low light but at low photosynthetic levels. When a stand is suddenly opened up through thinning, the trees (or overtopped part of each tree's canopy) have to adapt to the increased light by converting to sun needles, which are more efficient at photosynthesis. This process can take a year or two. Fertilization soon after thinning will help the tree undergo this adaptation but can overload the tree with heavier foliage, as shown in the measurements in the above table. If the tree has a high height/diameter ratio, the tree may be unable to withstand heavy snow or strong wind. These factors should be considered at the stand management prescription stage when thinning and fertilization are considered for a stand.

Operational Planning Regulation

Part 6 – Stand Management Prescriptions

Treatments and objectives for treatments

49. (1) For the purposes of section 24(2.1) of the Act, the treatments may be one or more of the following:

(c) fertilization

Content of stand management prescriptions

50. (3) A stand management prescription must, for each standards unit, specify all of the following:

(j) if the proposed treatment is fertilization,

(i) the type of fertilizer,

(ii) the rate of application,

(iii) the method of application,

(iv) the season the proposed treatment is to be carried out, and

(v) if in a community watershed, the known water quality objectives.

Overhead: Operational Planning Regulation

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(v) if in a community watershed, the known water quality objectives.

Silviculture Practices Regulation

Division 3 – Stand Management

Use of fertilizers

21. (1) A person who carries out a silviculture treatment and uses fertilizer must store, handle and apply the fertilizer in a manner that protects forest resources.

(2) A person who carries out a silviculture treatment and who applies fertilizer other than on spot areas in a community watershed must not

(a) apply fertilizer

(i) closer than 100 m upslope of a water intake, or

(ii) within 10 m of a perennial stream that is observable from the air, at the height the fertilizer will be applied, unless otherwise authorized by both the district manager and the Minister of Health, and

(b) cause

(i) nitrate nitrogen levels in a stream to exceed 10 ppm measured immediately below the area where the fertilizer is applied,

(ii) chlorophyll levels to exceed

(a) 2 micrograms/litre in a lake, or

(b) 5 milligrams/square metre in a stream, or

(iii) water quality to fall below any known water quality object

Overhead: Silviculture Practices Regulation

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(b) 5 milligrams/square metre in a stream, or

(iii) water quality to fall below any known water quality objectives.

Lesson 3

Forest Fertilization Program

45 minutes

Objectives

- Review and expand on the guidance found in the *Forest Fertilization Guidebook* on the strategic planning of fertilization
- Discuss the questions to address for meeting forest estate management objectives before embarking on a fertilization program
- Understand the importance of the careful consideration of forest fertilization as a management tool to meet forest estate objectives using the stand management prescription

Equipment Needs

- Overhead projector
- Lesson 3 transparencies
- Flip chart, wide-tip felt pens and masking tape

Method

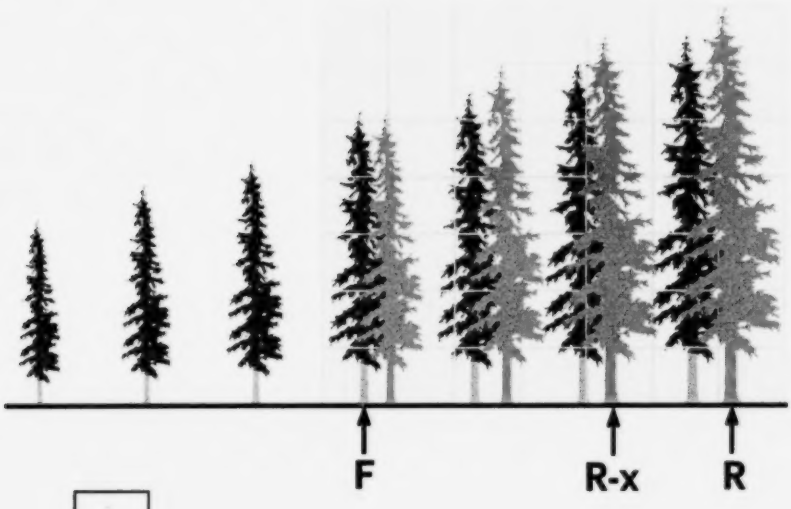
- Lecturette with overheads and group discussion using flip charts
- Case studies

Instructions

This lesson focuses on the strategic goals of a forest fertilization program. The facilitator will need to gauge the participants' experience with fertilization and the degree of their need for an introduction to strategic planning before beginning this lesson. In the group introductions, try to get an idea of how in-depth this lesson should be. All participants should receive some instruction from this lesson, but the facilitator will need to judge the level of detail and emphasis required. The questions to participants and case studies should be led by the facilitator accordingly.

Statements on the strategic purpose of fertilization are on page 1 of the *Forest Fertilization Guidebook* under the "Response to Fertilization" section and on page 7 under "Forest Level Planning." They state in part that one requires the knowledge of the timber supply profile and future wood supply needs, both spatially ("*What stands to fertilize?*") and temporally ("*When to fertilize?*"). With this information one can schedule fertilization of stands of a specific age class and species and optimize treatment investments. The overheads for this lesson will introduce participants to these concepts.

Fertilization as a Strategic Tool



F – Fertilized trees get boost in growth

R-x– rotation size can be reached sooner through fertilization.

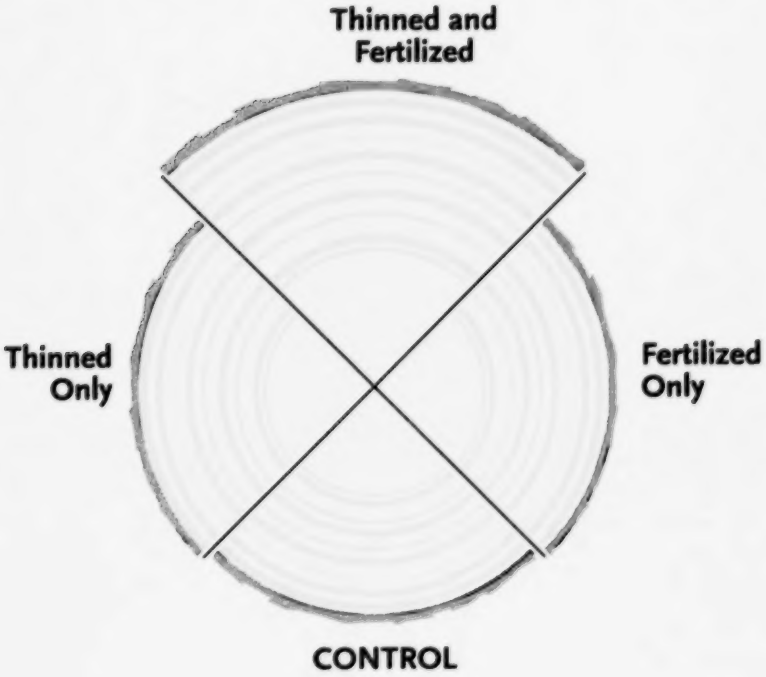
R – fertilization yields larger trees at natural rotation age.

Overhead: Fertilization as a Strategic Tool

Key Points

- The key response from forest fertilization is that the application of deficient nutrient(s) speeds up stand development, producing a stand with target properties (volume, diameter) earlier than without treatment. Or, a stand with a larger diameter and volume will be produced at the same rotation. A fertilized stand will not otherwise differ significantly from a non-fertilized stand grown over a longer rotation. *This is one of the basic tenets of forest fertilization.*
- Fertilization is subsequently used to accelerate the development of specific age classes and timber types in conjunction with the timber supply profile and the timing and magnitude of projected wood supply needs.
- A well-planned fertilization program can therefore be used to facilitate an even supply of wood at the forest-estate level.
- Fertilization programs should be planned and implemented as part of an overall enhanced forestry strategy that includes juvenile spacing and pruning. This will ensure that fertilization treatments are optimized on selected crop trees that will maximize stand value at harvest.
- In summary, fertilization is not a sole treatment on an ad hoc basis; it must be incorporated at the forest-estate planning level to maximize returns on timber values from merchantable stands and to mitigate projected timber supply shortfalls.

Response to Fertilization



Overhead: Response to Fertilization

Key Points

- Overhead shows control (no treatment) on the bottom, thinned only on the left, fertilized only on the right, and thinned and fertilized on the top
- Note how thinning or fertilizing as single treatments produce a small response, whereas together, the response is dramatic
- The response from fertilizing only would depend on stand density and the potential for response
- This overhead shows how a fertilization program must be planned as part of an overall enhanced forestry program with treatments for each candidate stand carefully planned and properly conducted to produce the desired effect and optimize the investments of the treatments

Exercise: (Facilitator addresses entire group or delegates one question per sub-group)

- *Note that these questions are posed in a chronological sequence. The facilitator should point this out to participants when the questions are all addressed and ensure that participants understand this important sequence as part of strategic planning of fertilization.*

1. Do you have defined investment priorities for the funds you spend on fertilization? If not, how should priorities be determined to set up the program?
2. Do you have defined stand targets for determining the rotation age of different tree species across all sites? If not, how would you go about defining them?
3. How would you determine either the reduction in the rotation age or the increase in wood volume from fertilization treatments?
4. How would you decide if you have sufficient land area by age class to fertilize and have a significant impact on the wood supply?
5. What operational falldown factor do you apply to the research results for modeling stand response from fertilization?
6. What should be part of a long-term monitoring plan for the measurement of growth response to fertilization?

Responses

1. Do you have defined investment priorities for the funds you spend on fertilization? If not, how should priorities be determined to set up the program?

   There should be defined investment priorities based on age classes for fertilization. In other words, what is the age class distribution of the forest? Then determine priorities using the stand selection guidelines in the Forest Fertilization Guidebook *and develop a 5–10 year program based on the priorities and the individual stands' "readiness" for fertilization. A stand may be currently too young for fertilization but may become a high priority at the end of the planning timeframe when it is a more suitable age for treatment.*

2. Do you have defined stand targets for determining the rotation age of different tree species across all sites? If not, how would you go about defining them?

   Use yield projection models, such as TIPSY, stand density management diagrams or Prognosis, to determine rotation by species and site. Empirical data and observations could be helpful to adjust model results for application.

3. How would you determine either the reduction in the rotation age or the increase in wood volume from fertilization treatments?

   The response should relate back to the basic premise of fertilization, as shown in Overhead 3•1. Fertilization can produce the same-sized tree in a shorter timeframe or produce a larger-diameter tree if the rotation age is unchanged. It is important to define why the rotation would be shortened or wood volume increased – this depends on projected wood supply and the anticipated increased value of a larger piece size.

4. How would you decide if you have sufficient land area by age class to fertilize and have a significant impact on the wood supply?

   For a 10-year program, for example,what is the number of hectares that could reasonably be fertilized each year? Multiply this number by the average expected volume response rate per hectare. The increased overall volume harvested per year is the Allowable Cut Effect (ACE). *Decide if this amount will produce a significant impact on the wood supply at the forest estate level.*

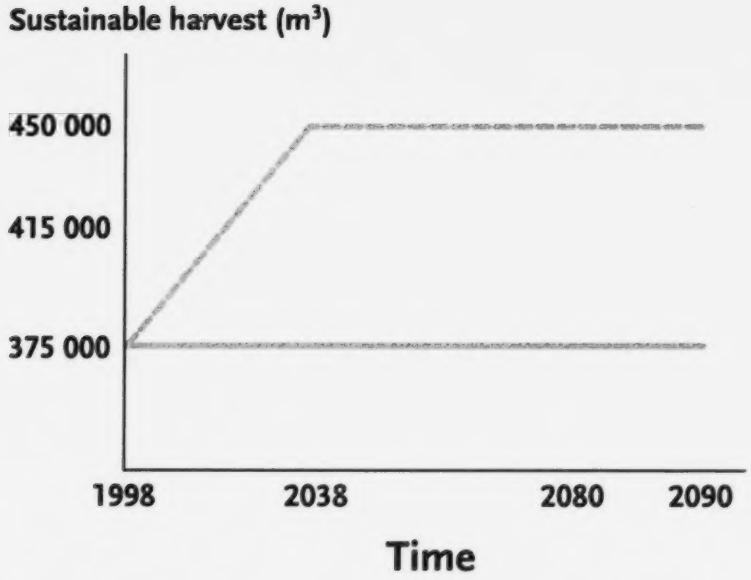
5. What operational adjustment factor (OAF) do you apply to the research results for modeling stand response from fertilization?

   If the OAF1 from incomplete stocking means a 15% reduction in yield, fertilization, if properly prescribed and conducted, would be able to offset this reduction to some extent, for example to 10%. This results in a net gain in yield compared to an unfertilized stand. OAF2 (regarding forest health concerns) may be reduced similarly or it may actually increase if fertilization increases forest health agents and reduces net yield.

6. What should be part of a long-term monitoring plan for the measurement of growth response to fertilization?

   A long-term monitoring plan could include growth and yield plots, forest health monitoring (especially if problems are suspected), Sx trials, E.P. (experimental project) research trials, foliar sampling 5 years after fertilization to determine response and decide whether or not to refertilize.

Forest Fertilization Case Study
(Coast)



Overhead: Forest Fertilization Case Study (Coast)

The private land base of this managed forest consists of approximately 80 000 ha of forested land. The even-flow, long-run sustainable rate of harvest is estimated at 375 000 m^3 if these lands were unmanaged. The management practices employed to date and currently used – such as immediate reforestation, achieving free growing status, conducting juvenile spacing, and fertilization at the time of spacing – are expected to sustain a harvest of 415 000 m^3 which could be increased to 450 000 m^3 in 2038.

The company's long-term wood requirements indicate that within 20 years, and due to the expiration of Old Temporary Tenure licenses, the harvest from these private lands should be closer to 500 000 m^3. However, simulations with a forest estate model indicate that this level of harvest is not sustainable with current practices. To reach this target it has been determined that the management strategy must include fertilizing 4000 ha/year of stands about 10 years before harvest. The estimated gain in volume from this strategy is approximated at 15 m^3/ha or a total gain of 60 000 m^3 of harvest volume. This treatment should take place starting immediately and continue for the next two decades. Such a management strategy has been shown to allow the harvest of 480 000 m^3/year through to 2038 and an increase to approximately 500 000 m^3/year thereafter. This cut level could then be maintained indefinitely, provided such a program of fertilization was repeated again during the period of 2080 and 2090, thereby offsetting a projected deficit anticipated to occur during the period 2095 and 2104.

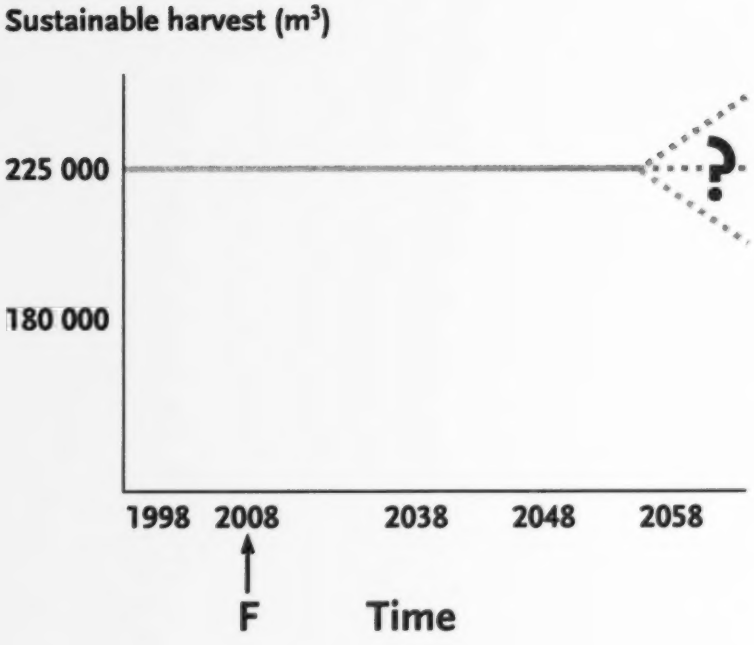
It is expected that fertilization approximately 10–15 years before harvest should accelerate the growth of the stand and help overcome a projected wood supply problem by producing 15 m^3/ha greater yield at 60 years of age. The diameter distribution after the treatment would shift stems into the merchantability category and increase the stand average diameter by about 3 cm. The range of diameters is reduced because increased between-tree competition will remove numbers of smaller understorey trees. Harvest costs will be reduced because fewer trees will be handled.

Summary

Forest fertilization is a silvicultural treatment that must be applied with discretion and proof that it is an appropriate strategy for the wood supply problem. It requires a strong guarantee of security over the land base so that the benefits can be counted on for the near and longer term. It works best where there is a stand-based information system that can relate to the future wood supply needs and harvest scheduling. Finally, there is a need for reliable growth and yield information to assist in prescribing the most effective and timely application of the fertilization treatments.

Forest Fertilization Case Study

(Interior)



Overhead: Interior Forest Fertilization Case Study

A typical age class structure of many interior forest management units consists of a substantial area of young stands and a large area of old growth stands with little or no area in the intermediate age classes. The development of the forest age-class structure resembles a wave, with a harvest level in the near term based on the reduction of the initial standing old growth. If this rate exceeds the time necessary for the current young stands to develop into merchantable stands, there is a sudden and rapid timber supply falldown in the future.

Even if the rate of harvest is sufficient to allow the young stands to grow to merchantable size, these "new" harvestable stand types will typically have less standing volume than the previous old-growth stands because the age at which a stand is scheduled for harvest will probably be the culmination of mean annual increment and not the point of maximum standing volume. This is a simplified explanation of the falldown effect so common to the province's forest management units.

In this example, without forest fertilization, the harvest volume cannot be sustained at 225 000 m^3/year past 60 years in the future, after the year 2058. This is not simply because the second growth stands were not given sufficient time to reach merchantability; in fact, some second growth stands are harvested as early as 41 years from present. The reasons are that some of the stands in the oldest age classes are assumed to be lost to insects and diseases. These stands recycle back onto the regenerated yield curve but have not provided any volume to the harvest. As well, the standing volume of the regenerated stands when harvested is up to 50 m^3/ha less than that of the old growth stands.

Clearly, the only way to maintain the present harvest level of 225 000 m^3 is to apply those silvicultural treatments that will result in earlier merchantability and greater volume at a younger age. Before reading further, sketch the shape of the volume over age curve on the curve shown for this base case. What is the magnitude of the differences?

The application of fertilizer to only 50% of the stands was found to be adequate to bridge the wood supply problem at 60 years from the present. The shape of the yield curve assigned to this treatment and the stand types to which it was applied are known. The effect of the fertilization is represented in the diagrams and described as follows: **The fertilization yield curve does not give more volume per hectare, but rather it produces a similar volume at a younger age and reduces the age of merchantability.** This is a basic tenet of forest fertilization as a silvicultural treatment for reducing projected timber supply falldowns.

The age-class structure develops much as before for the initial 40 years, except that now as the initial harvested area begins at 1000 ha/year, it can quickly increase with the availability of the fertilized stands reaching merchantability sooner. Now the second growth stands that are harvested 41 years from present have standing volumes similar to stands 15 to 20 years older. The fact that 50% of the second growth stands now have volumes similar to the pre-existing old growth stands means that the area harvested does not need to increase as much. The one caveat that should be mentioned, however, is that the fertilized stands are preferentially harvested in the initial stages. The repercussions of this policy is that when the unfertilized second growth stands are harvested, at least half of them will have to be fertilized to perpetuate this strategy. Therefore, the entire forest is assumed to consist of potential fertilization candidate stands, an unlikely occurrence in many areas.

In summary, different forest estates have different opportunities to maintain or increase timber supply from a strategically planned forest fertilization program. There is also the potential from fertilization to maintain revenue to the Crown from timber harvesting while harvesting less area because each fertilized hectare of forest is producing more volume.

Stand Management Prescription

- Use Section D-1 Post-treatment Standards
- Fertilization included as treatment under 'Schedule'

Year	Age/ Height	DBH	Treatment	Area (ha)
1996	18/7	6.5	Juvenile space 800 sph	22.7
1997	19/7.5		Prune	22.7
1998	20/8.6	9.2	Fertilize @ 250 kg N/ha	24.0
2002	24/11.5	15.6	Prune	22.7
2005	27/13	19	Fertilize @ 250 kg N/ha	24.0
2038	60/30	37	Harvest	22.7

For more information refer to the *Stand Management Prescription Guidebook* (1999)

Overhead: Stand Management Prescription

Key Points

Lesson 4

Biological Factors

40 minutes

Objectives

- Review the eight biological factors from the *Forest Fertilization Guidebook* to consider in the ranking of stands for forest fertilization
- Review the guidelines and statements of advice found in the *Forest Fertilization Guidebook* that are important for selecting stands for fertilization

Equipment Needs

- Overhead projector
- Lesson 4 transparencies
- Copy of *Forest Fertilization Guidebook* for each participant (included in workbook)
- *Forest Fertilization in British Columbia* video
- Television and VCR

Method

- Video learning
- Lecturette with overheads and group discussion

Instruction

Begin by showing the video *Forest Fertilization in BC,* playing up to the end of the stand selection segment. This will provide a summary of the previous lessons and introduce the participants to the material in this lesson. Note that there are some changes since the video was produced. For example, transponders for aerial navigation have been replaced with GPS systems.

Ask the participants if they have any questions, any personal experience to add to the video, or any concerns relating to what the video shows.

The eight biological factors covered in this lesson are:

- species
- age and size
- stand density
- soil moisture and nutrient regimes
- site quality
- crown condition
- nutrient diagnosis
- insects, disease and small mammals

Lecture notes for this lesson are contained in the *Forest Fertilization Guidebook,* which is on the web at:

http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/fert/ferttoc.htm.

The overheads for this section display the guidelines or statements of advice from the guidebook.

Biological Factors

Overhead: Biological Factors

Key Points

- Once the strategic issues have been addressed, biological factors are a key component for evaluating each potential stand

Biological Factors

- Species
- Age and size
- Stand density
- Soil moisture and nutrient regimes
- Site quality
- Crown condition
- Nutrient diagnosis
- Insects, disease and small mammal damage

Overhead: Biological Factors

Key Points

- Minimize the time on this overhead since each point will be discussed in more detail with relevant overheads
- Each candidate stand must be evaluated for these eight key biological factors before a decision to fertilize can be made
- The *Forest Fertilization Guidebook* covers biological factors very thoroughly

Coastal Species

Douglas-fir **Western hemlock** **Sitka spruce**

√ ? (√)

Overhead: Coastal Species

Key Points

- Show the coastal/interior overhead that is appropriate to the workshop location and audience
- Coastal Douglas-fir has been the subject of extensive research on its response to N fertilizer
- Western hemlock has received some research but the results are not definitive
- Sitka spruce responds well but is threatened by the white pine weevil. Analysis of forest health concerns, in particular the risk of increased white pine weevil damage, is essential before prescribing fertilization of Sitka spruce.

Question: What are your experiences with species fertilized?

Interior Species

Lodgepole pine

√*

Wetbelt Douglas-fir

(√)

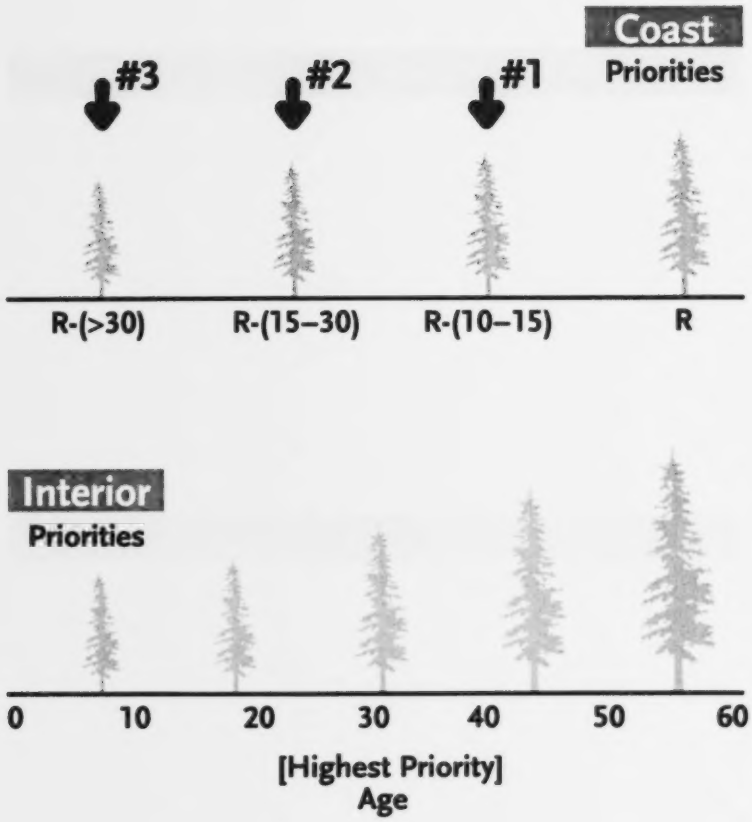
Overhead: Interior Species

Key Points

- Lodgepole pine has received extensive research and can be anticipated to respond well to N fertilization, **however**, sulphur (S) may be required in the fertilizer mix. Foliar analysis will help to determine this need.
- Lodgepole pine may also be deficient in boron (B). A nitrogen-induced deficiency (i.e., from fertilizing with N only) will produce dead tops and eventually multiple leaders, which is very undesirable and eliminates the usefulness of the fertilization treatment altogether.

Question: What are your experiences with species fertilized?

Age



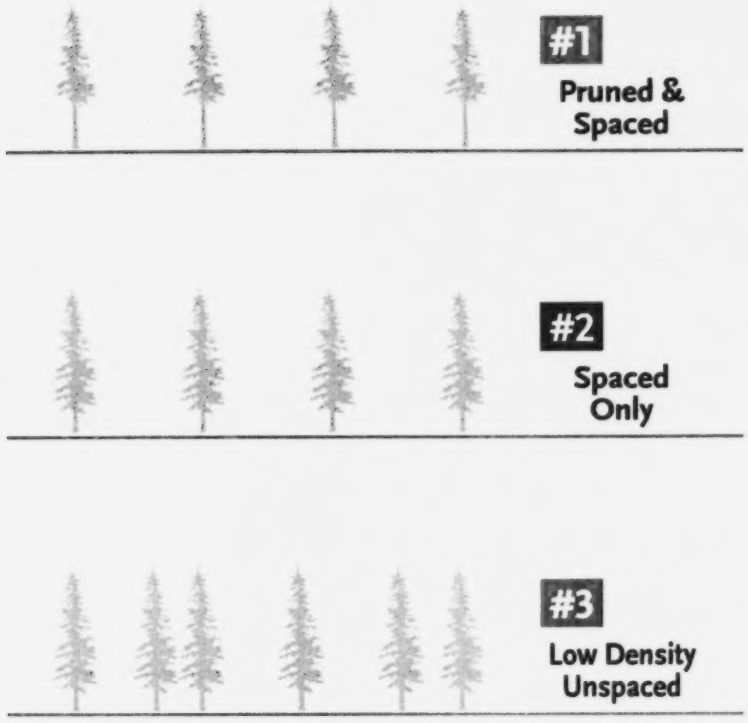
R = Response
(>30) = Number of years for response to occur.

Overhead: Age

Key Points

- The objective is to minimize the period of financial investment of the fertilization treatment cost while ensuring a high potential for increased growth
- Other factors have to be considered, however, so not all prescriptions should necessarily have to follow the age guideline exactly

Stand Density

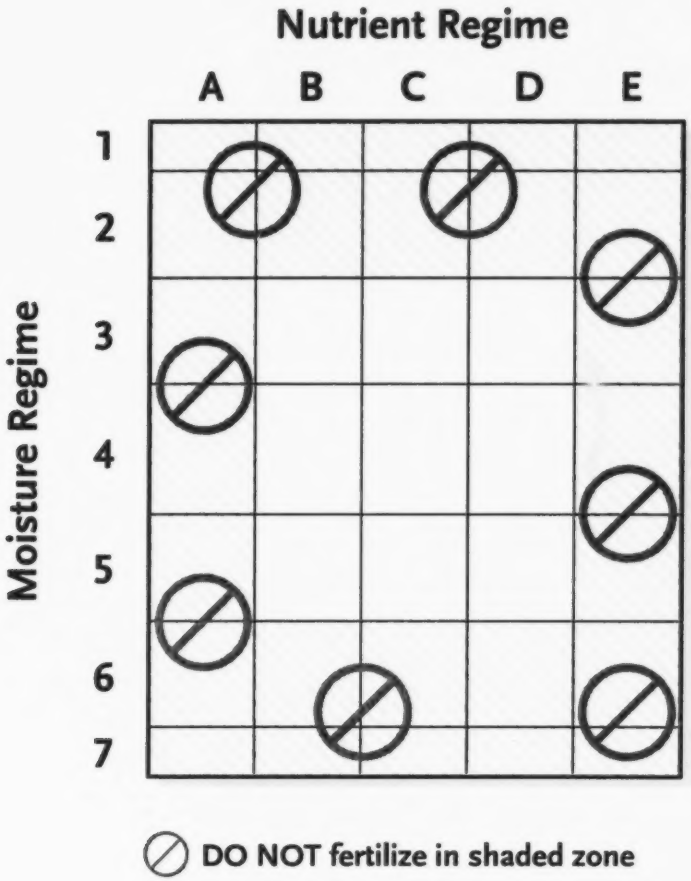


Overhead: Stand Density

Key Points

- Pruned stands have the potential to grow clearwood and thus are the highest priority for fertilization
- Favourable spatial distribution of the stand means that there is sufficient room for significant crown expansion after fertilization, which is critical for realizing the potential of the fertilization treatment investment
- Fertilizing before spacing locks up the fertilized nutrients organically in the spacing slash and provides a beneficial slow release of nutrients to the crop trees
- Beware of the potential vulnerability to wind and snow damage of a fertilized stand with a heavier crown. No stand with a height/diameter ratio of greater than 100 should be fertilized, and for Douglas-fir, a ratio less than 85 is recommended.
- Fertilization too soon after spacing, when there is still a covering of fine slash on the forest floor, may be unnecessary since the slash decomposition is fertilizing the crop trees and the slash may prevent the fertilizer prill from reaching the soil

Soil Moisture and Nutrient Regimes

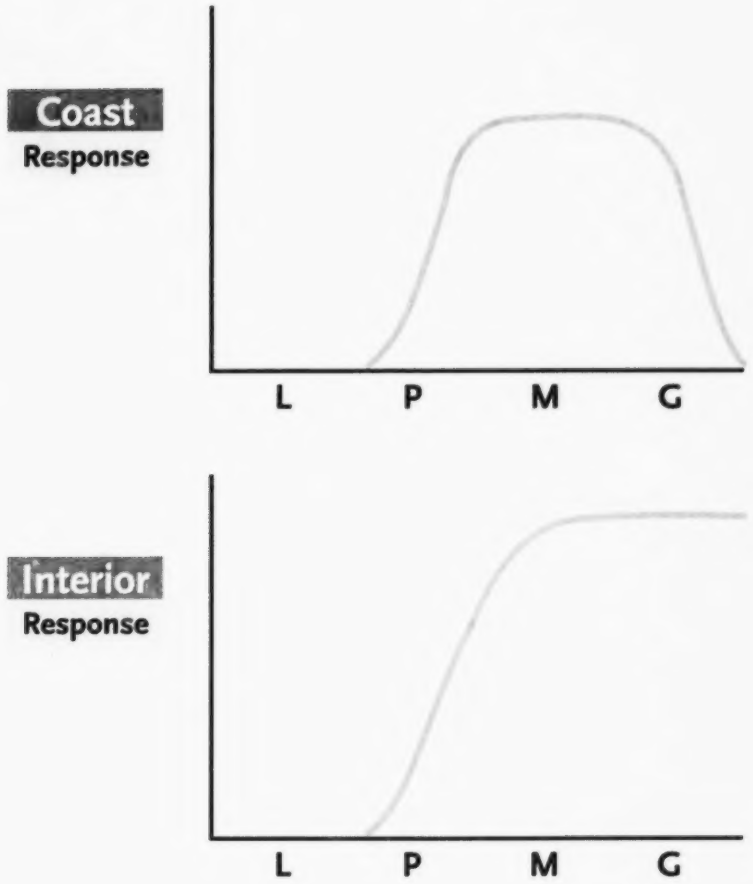


Overhead: Soil Moisture and Nutrient Regimes

Key Points

- The edatopic grid shows the sites that should not be fertilized; however, there is no clear line on the grid for delineating whether or not to fertilize
- When prescribing fertilization, only the prescribed nutrients can be the limiting factor to tree growth, or the treatment costs are wasted
- Therefore, do not treat very dry or very wet sites where water is the limiting factor for tree growth, or very poor or very rich sites where nitrogen is not the limiting factor

Site Quality



Overhead: Site Quality

Key Points

- Absolute response (net volume increase) to fertilization is higher on poorer sites than best sites
- Absolute response on good sites and under best site conditions (roughly midpoint on edatopic grid) may be desirable at forest estate level
- Highest priority is generally to fertilize poor and medium sites
- Do not fertilize low sites anywhere in BC. Most interior low sites have soil moisture deficit or extreme climate
- The next overhead illustrates the concept of relative and absolute growth increases.

Relative vs. Absolute Growth

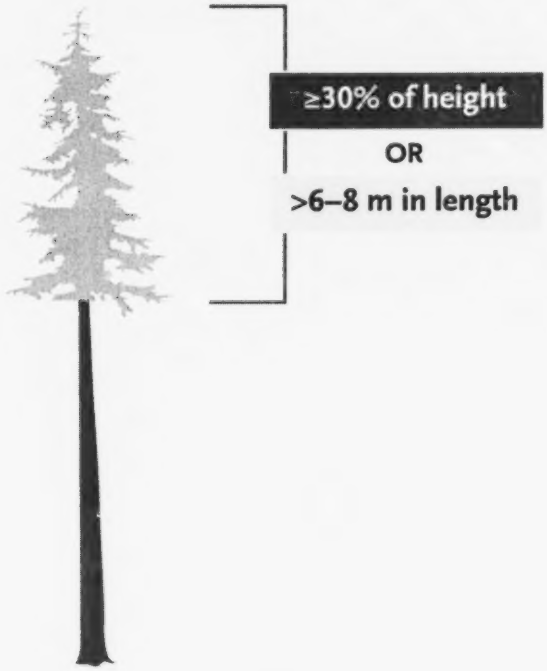
	Site Class	
	Low	Medium
Merchantable volume	100 m^3	250 m^3
% increase due to fertilization	20%	20%
Absolute increase	20 m^3	50 m^3

Overhead: Relative versus Absolute Growth

Key Points

- The same % increase from fertilization produces different absolute increases in volume and significantly different costs/ha overall
- Low sites do not have the potential in volume gains to offset the treatment costs
- Good site not used for example because nutrients are not usually a limiting factor

Crown Condition



Overhead: Crown Condition

Key Points

- The size and condition of live crowns provide an indication of the stand's nutrient status and productive potential
- The live crown should comprise at least 30% of total height or be greater than 6–8 m in length
- Small crowns do not have the overall potential to increase tree growth after fertilization (the 'factory' is too small) and may indicate stunted growth from reasons other than nutrient deficiencies
- Small crowns also usually indicate a high height/diameter ratio (>100) after excessive inter-tree competition from a high stand density, which disqualifies the stand as a candidate for fertilization anyway

Visual Symptoms

Overhead: Visual Symptoms

Key Points

- Very complicated to diagnose nutrient deficiencies by analyzing visual symptoms of the foliage, such as chlorosis
- Symptoms may differ between tree species and mild deficiencies may not be expressed
- Visual signs may be from a combination of factors, including non-nutritional
- Do not rely on visual symptoms for prescribing fertilization

Nutrient Diagnosis

Overhead: Nutrient Diagnosis

Key Points

- Foliar analysis is the last step in prescribing a stand for fertilization and should only be undertaken after the candidate stand meets all other wood supply, biological and operational criteria
- Collect in late fall/early winter to allow for adequate time for laboratory analysis of samples and data interpretation
- Arrange for foliar sampling before samples are collected (regional stand tending forester or fertilization specialist will know what labs are best) for the lab to schedule analysis
- Samples demonstrating straightforward analysis results, such as only one apparent nutrient deficiency, are the highest priority for fertilization. When a nutrient level is in the deficit range, that nutrient is likely a limiting factor to tree growth.
- Do not "beef up" a moderate level of nutrient to try to maximize growth unless prior experience on similar sites indicates that this is desirable. There is serious potential for toxicity, which degrades the stand at the expense of the treatment.

Forest Health

- Overall interaction between forest fertilization and forest health agents is poorly understood
- Current damage may increase
- Outgrow small mammal damage?
- Interaction from associated treatments?
- Local experience
- Forest health specialists

Overhead: Forest Health

Key Points

- The overall interactions between forest fertilization and forest health agents is poorly understood
- Interactions will include effects of associated treatments such as juvenile spacing
- Current forest health damage may increase after fertilization, since fast-growing trees become more attractive to pests that feed on them
- A healthy tree may be able to outgrow small mammal damage, even if damage does occur, but this is a risky premise
- Local experience contributes to the knowledge base
- Consult with forest health specialists before prescribing a suspect stand for fertilization

Lesson 5

Operational Factors

20 minutes

Objectives

- Review the four operational factors from the *Forest Fertilization Guidebook* to consider in ranking stands for fertilization

Equipment Needs

- Overhead projector
- Lesson 5 transparencies
- Copy of *Forest Fertilization Guidebook* for each participant (included in workbook)
- Flip chart, wide-tip felt pens and masking tape

Method

Lecturette with overheads and group discussion

Note

Instructions

This brief section completes Lessons 3 and 4 dealing with stand treatment ranking factors. Be prepared to supply some specific values or conditions for operational factors where your localized fertilization operations would be made difficult, more costly or generally undesirable. These will be listed on the flip chart for all participants to see.

The four operational factors are listed on page 19 of the *Forest Fertilization Guidebook*.

Operational Factors

Overhead: Operational Factors

Key Points

- Once the biological factors have been addressed, operational factors (feasibility) are the next key component for evaluating candidate stands

Operational Factors

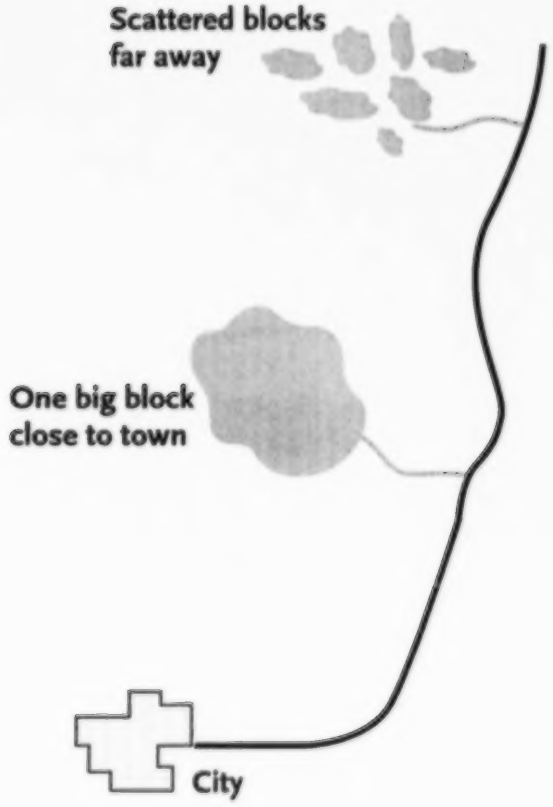
- Location
- Access
- Slope
- Project and block size

Overhead: Operational Factors

Key Points

- Operational factors affect project cost and overall feasibility of fertilization and related treatments
- Don't spend long on this overhead as the factors are discussed individually in the following overheads

Location



Overhead: Location

Key Points

- Long distances from main road and manufacturing centre will increase treatment costs and reduce net benefit of fertilization
- This point is exacerbated when water transport is included, unless water transport is the main or only means of access for those stands

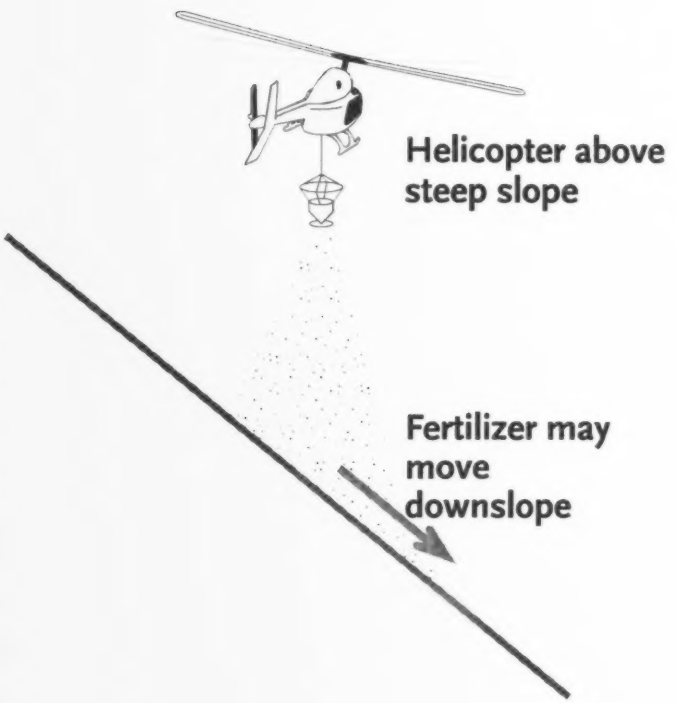
Access

Overhead: Access

Key Points

- Access problems can plague a fertilization project with logistical difficulties, especially if the weather gets bad and the secondary roads break up
- Consider the access implications for future treatments (including harvesting) when proposing a stand with poor access for fertilization

Slope

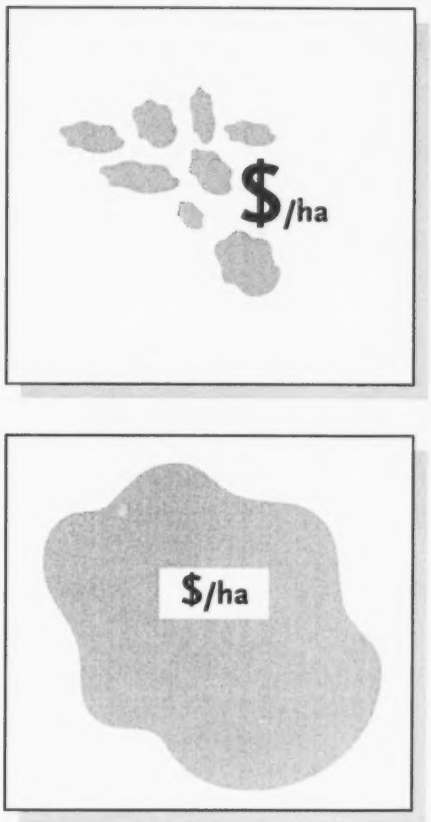

Helicopter above steep slope
Fertilizer may move downslope

Overhead: Slope

Key Points

- Steep slopes have similar effects to poor access except that even application of fertilizer may be difficult to achieve
- However, even application is not as critical for fertilization as for herbicide application

Project and Block Size



Overhead: Project and Block Size

Key Points

- Concentrate a fertilization project on a specific area for more cost-effective operations
- Consider combining Ministry of Forests and licensee fertilization programs to further improve the economy of scale and reduce per hectare treatment costs

Lesson 6

Stand Selection

30 minutes

Objectives

- Summarize the three main types of constraints to fertilization (strategic, biological and operational)
- Demonstrate a method of using stand attribute information to rank an individual stand for forest fertilization
- Test the participants' ability to recognize types of constraint factors for fertilization

Equipment Needs

- Overhead projector
- Lesson 6 transparencies

Method

Lecturette with overheads and group discussion

Instructions

The three areas that may constrain forest fertilization are: strategic (related to wood supply), biological and operational. A strategically unsuitable site is one that does not address projected timber supply falldowns. Numerous examples of this type of constraint exist, such as insufficient area of a tree species responsive to fertilization, a lack of stands of the required age class, and lack of growth and yield information for tree species that predicts positive, cost-effective growth responses. A biologically unsuitable site is one limited by significant climatic and soil moisture constraints for tree growth. The higher elevations of some subzones and the exceptionally dry conditions of the Chilcotin Plateau are examples. Operationally unsuitable sites are those on which the economics for application or realization of the growth response are limited by geographical constraints. Remote locations, such as along the coastal inlets, or areas prone to access problems due to road and bridge floodings, are examples of this constraint.

If a stand can pass through this key constraint to reach the potentially suitable designation, it will be given further examination. The failure of a stand to satisfy all conditions is reason enough to exclude it from current consideration. A factor may change with time (e.g., if good access is

developed) so the record for the opening should include the specific reason for its elimination. There is a short exercise to end this lesson which tests the participants' ability to identify which of the three guideline factors covered in this lesson is the most likely constraining factor to forest fertilization. They should first read the following case study to suggest the next actions to determine the ranking of this stand for fertilization.

Coastal Douglas-fir Case Study

Scenario: You are a silviculturist in the Sunshine Coast Forest District. You have been asked to evaluate the following stand of Douglas-fir for inclusion in an aerial fertilization program which currently consists of 630 hectares.

Stand Data:

The inventory database and the silviculture history records provide you with the following:

Total area:	120 ha
Dominant tree species:	Douglas-fir (Fd)
Minor tree species:	Western redcedar (Cw) < 10%
BEC subzone:	CDFmm
Site association:	Douglas-fir – Salal
Estimated site class:	Medium (SI = 25 m)
Establishment history:	Planted in 1950 with Fd 2+0 BR
Stand tending history:	Spaced in 1980 to 800 sph
Other:	No insect, disease or wildlife concerns

* All the operational factors and strategic objectives are acceptable for the stand.

What should you do next to determine the ranking for a fertilization treatment of this stand?

NOTES:

Coastal Douglas-fir Case Study

Facilitator's Guide Response

Scenario: You are a silviculturist in the Sunshine Coast Forest District. You have been asked to evaluate the following stand of Douglas-fir for inclusion in an aerial fertilization program which currently consists of 630 hectares.

Stand Data:

The inventory database and the silviculture history records provide you with the following:

Total area:	120 ha
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Estimated site class:	Medium (SI = 25 m)
Establishment history:	Planted in 1950 with Fd 2+0 BR
Stand tending history:	Spaced in 1980 to 800 sph
Other:	No insect, disease or wildlife concerns

* All the operational factors and strategic objectives are acceptable for the stand.

What should you do next to determine the ranking for a fertilization treatment of this stand?

Refer to the *Forest Fertilization Guidebook*, Appendix I.

Factor	*Score*
Area	1
Dominant species	1
BEC subzone and site association	1
Site class	1
Density	2 (1200 sph is rather high)
Age	1
Forest health	1
Total treatment area	1

This stand is a good candidate for fertilization. The age and its relation to rotation are not clear from the example, but this issue would be good for some group discussion. The stand's density is another issue for discussion. Is 1200 sph ideal? Should it be lower? What are the participants' experience with stand density for fertilization projects and the response in crown closure and duration of growth increase?

Interior Lodgepole Pine Case Study

Scenario: You are a silviculturist in the Prince George Forest District. You have been asked to evaluate the following stand of lodgepole pine for inclusion in an aerial fertilization program which currently consists of 630 hectares.

Stand Data:

The inventory database and the silviculture history records provide you with the following:

Total area:	120 ha
Dominant tree species:	Lodgepole pine (Pl)
Minor tree species:	White spruce (Sw) < 10%
BEC subzone:	SBSmk
Site association:	Bunchberry-moss (01)
Estimated site class:	Medium (SI = 19 m)
Establishment history:	Planted in 1970 with Pl 1+0 BR
Stand tending history:	Spaced in 1990 to 1200 sph
Other:	No insect, disease or wildlife concerns

* All the operational factors and strategic objectives are acceptable for the stand.

What should you do next to determine the ranking for a fertilization treatment of this stand?

NOTES:

Interior Lodgepole Pine Case Study

Facilitator's Guide Response

Scenario: You are a silviculturist in the Prince George Forest District. You have been asked to evaluate the following stand of lodgepole pine for inclusion in an aerial fertilization program which currently consists of 630 hectares.

Stand Data:

The inventory database and the silviculture history records provide you with the following:

Total area:	120 ha
Dominant tree species:	Lodgepole pine (Pl)
Minor tree species:	White spruce (Sw) < 10%
BEC subzone:	SBSmk
Site association:	Bunchberry-moss (01)
Estimated site class:	Medium (SI = 19 m)
Establishment history:	Planted in 1970 with Pl 1+0 BR
Stand tending history:	Spaced in 1990 to 1200 sph
Other:	No insect, disease or wildlife concerns

* All the operational factors and strategic objectives are acceptable for the stand.

What should you do next to determine the ranking for a fertilization treatment of this stand?

Refer to the *Forest Fertilization Guidebook*, Appendix I.

Factor	*Score*
Area	1
Dominant species	1
BEC subzone and site association	1
Site class	1
Density	1
Age	2
Forest health	1
Total treatment area	1

This stand is a good candidate for fertilization. The age is not ideal (score of 2) but is still acceptable. The stand density is suitable for lodgepole pine fertilization as the stand is open enough to benefit from fertilization without premature crown closure.

Which stand would you rather fertilize and why?

	STAND #1	STAND #2
Species	Pl70 Sx30	Pl60 Sx30 At10
Age	40 years	50 years
Density	1000 wsph (JS 1984)	1400 total sph Sx dominants with aspen in clumps
Ecosystem	SBSdk 05 submesotropic	SBSdk 05 mesotropic
Site Index	SI_{50} 18	SI_{50} 22
Forest Health	<5% insect and disease damage	<5% insect and disease damage
Access	Road washed out, need to rebuild bridge	Good access, near mainline
Slope	avg. 15%	avg. 15%
Block Size	120 ha	320 ha of cumulative blocks

Overhead: Which stand would you rather fertilize and why?

Facilitator's Guide Response

	Stand #1	**Stand #2**
Species	Pl70 Sx30	Pl60 Sx30 At10
Age	40 years	50 years
Density	1000 wsph (JS 1984)	1400 total sph, Pl and Sx dominants with aspen in clumps
Ecosystem	SBSdk 05 submesotrophic	SBSdk 01 mesotrophic
Site index	SI_{50} 18	SI_{50} 22
Forest health	< 5% insect and disease damage	< 5% insect and disease damage
Access	Road washed out, need to rebuild bridge	Good access, near mainline
Slope	avg. 15%	avg. 5%
Block size	120 ha	320 ha of cumulative blocks

Response

Factor	**Best Stand**
Species	Stand #1 has 10% more Pl
Age	Both stands are priority #1. Consider 30% Sx component and rotation length.
Density	Stand #1 has more room for crown expansion. At 50 years of age, Stand #2 is probably too dense for fertilization.
Ecosystem	Both stands in middle of edatopic grid and therefore good candidates for fertilization.
Site index	Stand #2 has higher SI but both are medium site.
Forest health	Both stands are fine but need to know what forest health agents present as they may respond differently to fertilization.
Access	Stand #1 may be a non-candidate based on need to rebuild bridge. Consider access required to area for other purposes and possibility of amortizing bridge work for more than this fertilization project.
Slope	Both slopes are fine, but Stand #2 has slightly better topography.
Block size	Need to see how many blocks involved and their size and configuration. Stand #1's total 120 ha is better and may compensate for rebuilding the bridge to gain access.

Site Constraint Factors Exercise

State whether the constraint factor is wood supply/strategic (S), biological (B) or operational (O) from the following site descriptions:

- ☐ **Soil moisture regime is very dry**
- ☐ **Site is located on a small island in Johnstone Strait**
- ☐ **Squirrel damage is evident in adjacent stands**
- ☐ **Site has a fluctuating water table**
- ☐ **Average slope is 35% with broken terrain**
- ☐ **Soil temperature rarely exceeds 10°C**
- ☐ **Limestone rock outcrops are common**
- ☐ **Roads and bridges into blocks are subject to washouts**
- ☐ **Rooting depth is < 30 cm**
- ☐ **Falldown has not been factored into Timber Supply Review**
- ☐ **Mineralizable-N rate is high**
- ☐ **Stand is situated on an active alluvial plain**
- ☐ **Visual green-up requirements restrict harvest opportunities**
- ☐ **Inventory database shows few Douglas-fir leading species stands in the management unit**

Site Constraint Factors Exercise

Answers for Facilitators Guide

State whether the constraint factor is wood supply/strategic (**S**), biological (**B**) or operational (**O**) from the following site descriptions:

B Soil moisture regime is very dry

O Site is located on a small island in Johnstone Strait

B Squirrel damage is evident in adjacent stands

B Site has a fluctuating water table

O Average slope is 35% with broken terrain

B Soil temperature rarely exceeds 10°C

O Limestone rock outcrops are common

O Roads and bridges into blocks are subject to washouts

B Rooting depth is < 30 cm

S Falldown has not been factored into Timber Supply Review

B Mineralizable-N rate is high

O Stand is situated on an active alluvial plain

S Visual green-up requirements restrict harvest opportunities

S Inventory database shows few Douglas-fir leading species stands in the management unit

Stand Selection Process

Overhead: Stand Selection Process

Key Points

- Lesson #6 is summarized through this flow chart
- Flow chart illustrates thought process in sequential order – strategic, biological, operational
- Imperative to assess candidate stands at each step to properly assess for fertilization

Lesson 7

Foliar Analysis

40 minutes

Objectives

- Describe the reasons and conditions for using pre- and post-fertilization foliar analysis
- Describe the time line and guidelines for collecting field samples and preparing them for shipment to a laboratory
- Examine the use of the critical level approach for the interpretation of the laboratory analysis

Equipment Needs

- Overhead projector
- Lesson 7 transparencies

Method

Lecturette with overheads, exercise and class discussion

Instructions

The subject matter for this lesson is found in Appendix 2 of the *Forest Fertilization Guidebook*. The purpose is to provide sufficient information for participants to collect foliar samples for analysis and interpret the laboratory results for use in stand selection. The commonly accepted critical level and interpretation tables will be explained and used in optional exercises located in the lesson with additional exercises in the appendix.

Key points to this lesson are:

- Foliar analysis should only be undertaken after a candidate stand meets strategic/wood supply, biological and operational criteria. Adequate time must be scheduled for the laboratory analysis.
- Distinguish between the differing purposes of pre-fertilization and post-fertilization foliar analysis.
- Review the methods of collecting foliage samples.
- Present drying methods of foliar samples prior to shipping to the laboratory.
- *(Optional)* Use the interpretation tables contained in the appendix to diagnose several examples of foliar analysis from a lab.

Foliar analysis is the chemical analysis, conducted by a laboratory, of the twelve nutrient elements important for tree growth. The results can be used to infer the nutrient status of a stand but not necessarily the reasons for a nutritional problem. Care must be taken when using foliar analysis for the purpose of prescribing fertilization. Foliar analysis is most useful for the identification of the severely deficient nutrients. Interpretative criteria are not available for all of British Columbia's tree species or for some elements; therefore, it is necessary to check the diagnostic criteria before sampling.

It is assumed that the stand selected for fertilization will utilize the applied nutrients quickly and produce improved tree growth. However, as part of program monitoring procedures, one should consider the use of pre- and post-fertilization foliar analysis. Foliar analysis can be used to measure nutrient status both before and after the fertilization treatment of the stand to quantify the increases in foliar nutrient levels and to identify any induced deficiencies. Therefore, on occasion, where a pre-fertilization foliar analysis is conducted to assist in the prescription for fertilization, and especially where mixed nutrient fertilizers are used, consider the use of post-fertilization foliar analysis.

There are seven foliar sampling guidelines to follow; these are listed in Appendix 2 of the *Forest Fertilization Guidebook* and below. The important points are to sample at the correct time of year, from dominant and co-dominant trees, away from foliage contamination sources, and to handle samples in the recommended manner. The samples of foliage can be collected using any of four techniques, often depending on the height of sample trees.

Computer-based programs are available to assist in the interpretation of the results from foliar analysis or the simple approach of comparing the laboratory results with the diagnostic critical level where it is available for that tree species. This latter approach is used with this course, in which a scenario is explained and the foliar analysis results provided.

Biological Assessment of Site Productivity
Inventory classification (LPMG)
Growth Intercept
OGSI
?
?
Tools to Determine Fertilization Potential
Screening Trials
Foliar Analysis
Other (PSPs)

Overhead: Biological Assessment

Key Points

- Use site index to determine if site is low/poor/medium/good
- The three tools shown (screening trials, foliar analysis and "other" such as permanent sample plots) expand on SI
- The tools are used to compare pre- and post-fertilization results to determine the effects of fertilization and the response

Foliar Sampling Guidelines

- **Sample in the fall**
- **Sample only dominants and co-dominants**

Foliar Sampling Guidelines (con't)

Overhead: Foliar Sampling Guidelines

Key Points

- Sampling must represent the average conditions in the stand without any bias from the growing season, dust or other variables
- The *Forest Fertilization Guidebook* covers drying methods well
- Sampling must be carefully conducted and the samples properly dried and shipped promptly to the lab
- The lab should be notified before the samples are shipped so that the analysis can be scheduled

Foliar Analysis

Pre-fertilization

- Composite samples from representative locations
- Stratify samples if necessary
- Complete laboratory analysis

Post-fertilization

- Needle weights
- Representative locations across flight lines
- Complete laboratory analysis

☆ Contact regional Stand Tending Forester or Rob Brockley, Kalamalka Research Station

Overhead: Foliar Analysis

Key Points

- Emphasize importance of screening trials if no other response information is available (e.g., for the species, area fertilized, etc.). Participants do not have to learn how to establish screening trials from this course. Instead, they should consult Appendix 3 of the *Forest Fertilization Guidebook* and contact the regional specialist (stand tending forester) for guidance on establishing them.
- Establish screening trials to compare pre- and post-fertilization foliar analysis. Use representative stands for the forest estate to use trial and operational $$ most effectively.
- District and licensee staff involved in fertilization operations can contact regional Stand Tending Forester or Rob Brockley at the Kalamalka Research Station for technical assistance.

Lesson 8

Contract Administration

40 minutes

Objectives

- Explain the important steps of the preparation, review and awarding of a fertilization contract
- Review the typical time line for a fertilization program
- Review the special measures required for the fertilization of areas within a community watershed

Equipment Needs

- Overhead projector
- Lesson 8 transparencies
- Updated contract documents (if changed from Participant's Workbook)

Method

- Lecturette with overheads
- Group discussion of contract experience

Instructions

A useful resource person for this lesson is the Ministry of Forests regional stand tending forester or a silviculture contract specialist from the region or district. The subject matter on forest fertilization contract administration has frequently undergone both structural and funding source changes. At the contract administration stage, the *Forest Fertilization Guidebook* should be used to refer to the special measures to follow if fertilizing within a community watershed, and the steps and time lines for sampling foliage or water.

This section will use the contract experience of the facilitator and participants to enhance the usefulness of the lesson for all. Participants with fertilization contract experience are encouraged to give examples of successful and problematic contract administration cases for fertilization projects, with group discussion of applying that experience for their future use.

Fertilization Program Time Line

Fertilization Contract Administration

Overhead: Fertilization Program Time Line

Key Points

- Regional specialist should coordinate a regional fertilization by soliciting interest from district silviculture staff and licensees during the late spring or summer for basing district funding requests for the fertilization program in the next fiscal year. Regions may amalgamate their areas for fertilization into one contract that covers the southern interior or northern interior regions. (Vancouver Forest Region often has enough area for an individual contract, and season of application is longer than for the interior.)
- Candidate stands for fertilization are identified using the principles in Lesson 3, beginning at the forest estate level and working down to the stand level. Foliar analysis is conducted to verify nutrient deficiencies in candidate stands.
- Stand Management Prescription (SMP) is prepared for stands with fertilization prescribed. Note that new Silviculture Practices Regulation allows for "bundling" of SMPs for better efficiency and much less paperwork.
- Advance time is required for fall foliar analysis, fertilizer order and Request for Proposal (RFP) for fertilizer application contract.
- Fertilizer order is handled by the Forest Practices Branch for all ministry and industry use.
- Regional stand tending foresters handle all RFP stages once districts have submitted block maps, fertilizer mix needs and other pertinent information.
- Stand tending foresters review proposals and select contractor for fertilization.
- Stand tending forester sends copy of contract to districts/licensees involved in fertilization program that year.
- Regional coordination of fertilization program and stand tending forester is in communication with Forest Practices Branch and districts/licensees.

- Fertilization program conducted with monitoring* throughout the application.
- To further streamline a regional fertilization program, a regional cooperative could be set up. This cooperative of Ministry of Forests, forest licensees, woodlot licensees, other agencies and the cooperative leader would coordinate all aspects of the regional fertilization program and help the program become more regionally efficient and effective. The cooperative leader could be an independent contractor responsible for stand selection, preparing SMPs and overseeing the application and monitoring phases of the actual fertilization project.
- The Forest Renewal BC new delivery model is currently under development for enhanced forestry programs, including fertilization.

* Monitoring a fertilization contractor's performance requires clear statements of the standards in the contract document and reviewed at the pre-work conference. The contract should detail the start and finish dates, obligations of both parties, scheduling of blocks, standards of performance, payment, suspension and cancellation, fire prevention, liabilities, and operational specifications including provisions for the protection of the environment.

Community Watersheds

- Specific designation
- Up to 30% per year with buffers as specified in guidebook, or maximum 12% of total area
- 100 m buffer above water intakes

Overhead: **Community Watersheds**

Key Points:

Lesson 9

Operational Fertilization

60 minutes

Objectives

- Explain the guidelines and statements of advice presented in the *Forest Fertilization Guidebook* section on fertilization method and application
- Review the checklist for operational fertilization projects
- Provide the necessary information to determine the elemental concentration, target application rate and total fertilizer when applying nitrogen, phosphorus, potassium, and sulphur
- Explain a method of determining both the swath length and time taken to disperse fertilizer from a spreader (hopper)
- Review an example of prescribing re-fertilization of stands
- Explain the importance of the air operations during the application phase
- Provide a model of a good contingency plan for handling accidental spills of fertilizer
- Explain the monitoring and reporting procedures that document compliance with the standards set out in the contract, stand management prescription and Silviculture Practices Regulation.

Equipment Needs

- Overhead projector
- Lesson 11 overheads
- *Forest Fertilization in British Columbia* video
- Television and VCR

Method

- Lecturette with overheads, exercises and class discussion
- Video presentation

Note: This lesson is one of the longest and has been broken down into three subsections:

- Fertilizers
- Frequency and timing of application
- Implementation plans and procedures

Key points to this lesson (by subsection) are:

Fertilizers

- Specifications of the type of fertilizer with amount of each nutrient to apply should be included in the stand management prescription (SMP) or silviculture prescription (SP).
- Calculating the amount of fertilizer to apply and therefore how formulations of fertilizer are described are used to determine application rates.
- An optional exercise in the appendix is provided to test the participants' ability to use the conversion table, prove that the operational mix used in the interior meets the stated application rate, and work with a complex mix of three nutrients.

Frequency and timing of application

- A calendar indicates the preferred seasons of the year for fertilizer application on the coast and in the interior.
- The re-fertilization of a stand should not occur until the initial fertilizer response has ended if the cost per unit response is important.
- A planning table is presented to assist in the long-term planning of refertilization and the escalating size of a fertilization program.

Implementation plans and procedures

- Air operations are especially important because currently all operational fertilization in BC is conducted using helicopters or fixed-wing aircraft.
- The pilot should be supplied with good quality maps and aerial photographs that have all buffers or No Fertilizer application zones clearly marked.
- Improvements in electronic guidance methods (use of GPS instead of transponders) provide greater accuracy and monitoring of application.

- Field inspections should include measurements of the application, inspection of equipment, survey of buffer zones, and notes about the weather conditions.
- An exercise to produce a sample contingency plan to handle accidental fertilizer spills will precede a review of a model provided in the lecture notebook.
- The overall purpose of the field inspection and reports for the fertilizer project are to comply with standards established in legal binding documents such as the fertilizer contract, the SMP and the Silviculture Practices Regulation.
- There are six main points to consider during the monitoring of aerial application to confirm compliance with standards.
- An exercise to calculate the swath length and time to disperse a spreader full of fertilizer is included in the appendix.

Air Operations

All operational forest fertilization projects in the province are currently conducted using helicopters or fixed-wing aircraft. Therefore, to ensure safe and efficient operations, the block boundaries, buffer zones, hazards and heliport locations must be discussed and agreed to with the contractor at the pre-work conference. Good quality maps and aerial photographs with clearly marked buffer and No Fertilizer application zones must be provided to the pilot. A 10 m No Fertilizer application zone is left around most lakes, streams and other important open water bodies. Within a community watershed, fertilizer must not be applied within 100 m upstream and upslope of watershed intake pipes.

Electronic guidance is very important to ensuring an accurate and even application pattern of fertilizer. Recent advancements in the area of Global Positioning Satellite (GPS) systems enables very accurate determination of the helicopter's position and flight path. While the pilot and project officer should work together to ensure even distribution of the fertilizer, the application does not need to be as accurate as aerial herbicide application, since tree roots are more dispersed than target vegetation foliage.

Field inspection of the aerial spreader or "hopper" should be made at random intervals of a fertilization project. Points to note include whether or not there is a metering system for loading the spreader and its proper use, use of a leakproof system employed to fill and dispense from the hopper, evidence of a uniform dispersal pattern during the flight and application, and proper functioning of the positive shut-off device under the control of the pilot.

The weather conditions during the time of fertilizer application can nullify the abilities of even the best pilots. Wind and visibility are two key problems that may be encountered which will necessitate the temporary suspension of operations. The only absolute for all personnel involved in fertilizer application is to put human safety as the highest priority in all aspects of the operations.

Season of Application

The guideline for the season of application is explained by targeting the ideal weather conditions that typically occur during the same time of the year. Generally, fertilizers should not be applied from April to approximately mid-September. It is more important to apply urea compared to some other fertilizers during cool and moist conditions due to urea's propensity to volatilize (rapidly evaporate) during warm air temperatures. It is not recommended to apply any fertilizer on frozen ground, crusted snow or slopes exceeding 30%.

Contingency Plans

A contingency plan in the case of accidental spills of fertilizer must be in place and approved by the district manager prior to the commencement of operational fertilization projects. The guidelines for a plan both within and outside of community watersheds is explained in the *Forest Fertilization Guidebook*. In addition to this contingency plan being available on site at all times, the material safety data sheet (MSDS) for the fertilizer, a copy of the fertilizer contract with maps and the silviculture prescription or stand management prescription are required.

There is no endorsed model of a contingency plan; however, a suggested model is provided in the appendices along with copies of the MSDS for urea and ammonium nitrate. The applicable legislation to accidental spills is the "Spill Reporting Regulations" of the *Waste Management Act*. A copy of this legislation is included and stipulates all the actions required in the event of a spill. The supplier of the fertilizer is also generally available for assistance in the event of a spill and their telephone contact number is found on the material safety data sheet.

Notes

Checklist for Operational Fertilization Projects

Project Title: _____

File #: _____

STEP	TASKS / SUGGESTIONS	✓
1 Cutblock identification	Collect data on strategic, biological and operational considerations, including economy of scale for a series of blocks to constitute a project (best >500 ha). Use operational plans, maps, electronic record systems, road recces, foliar analysis, screening trials to identify potential stands	
2 Tender package preparation	Tender package should include: - Updated maps - Aerial photos showing cutblocks for fertilization, stream buffers, No Treatment zones, road access - Clear, self-explanatory contract specifications - Minimum standards of equipment and safety - Spill Contingency Plan/Clean-up requirements - Personnel skills - Application techniques required - Concerns if fertilizing in a community watershed	
3 Advertise, review proposals, award contract	Advertising should cover British Columbia, Alberta, Saskatchewan, Washington, Oregon and Idaho	
4 Pre-work conference	Review all details with the contractor on: - Safety - Spill Contingency Plan/Clean-up requirements - Personnel - Application specifics **Review Fertilization Pre-Work Checklist**	
5 Staging (equipment mobilization, road upgrading)	Plans in place between contractor and district or licensee for any necessary access improvements	
6 Cutblock boundaries	Mark all buffer strips around reserves, streams, edges and No Treatment zones using paper rolls, balloons or other methods	
7 Calibration of application rates	Calibrate application rate of fertilizer from spreader to ensure prescribed application rate of fertilizer/ha is applied	
8 Monitoring of fertilizer application	Monitor application rate, buffers, spills, waterbodies using on-site viewing of application (swath wide/overlap) and missed patches. Check for prill in buffers, streams and other No Treatment zones	
9 Monitoring of water quality	As outlined in *Forest Fertilization Guidebook*	
10 Contract payment	Review all phases of contract when work completed to determine appropriate payment	
11 Reporting	Report all treated blocks on electronic record system	

Overhead: Checklist for Operational Fertilization Projects

Key Points

- Link checklist on overhead with time line overhead (Overhead #8•1).
- The steps on the checklist include regional and district responsibilities. Use the time line overhead to distinguish. Be sure that this is clear for the participants.

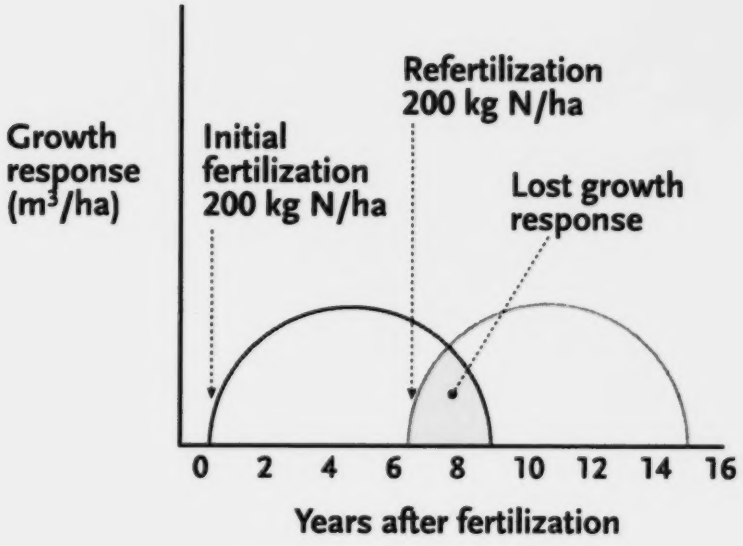
Refertilization

- Refertilization before the initial application response terminates reduces the potential total growth response
- Response is sustained longer with repeat treatments over one treatment

General Rule

- Coast – Refertilize every 8–10 years
- Interior – Refertilize every 5–7 years

Refertilization

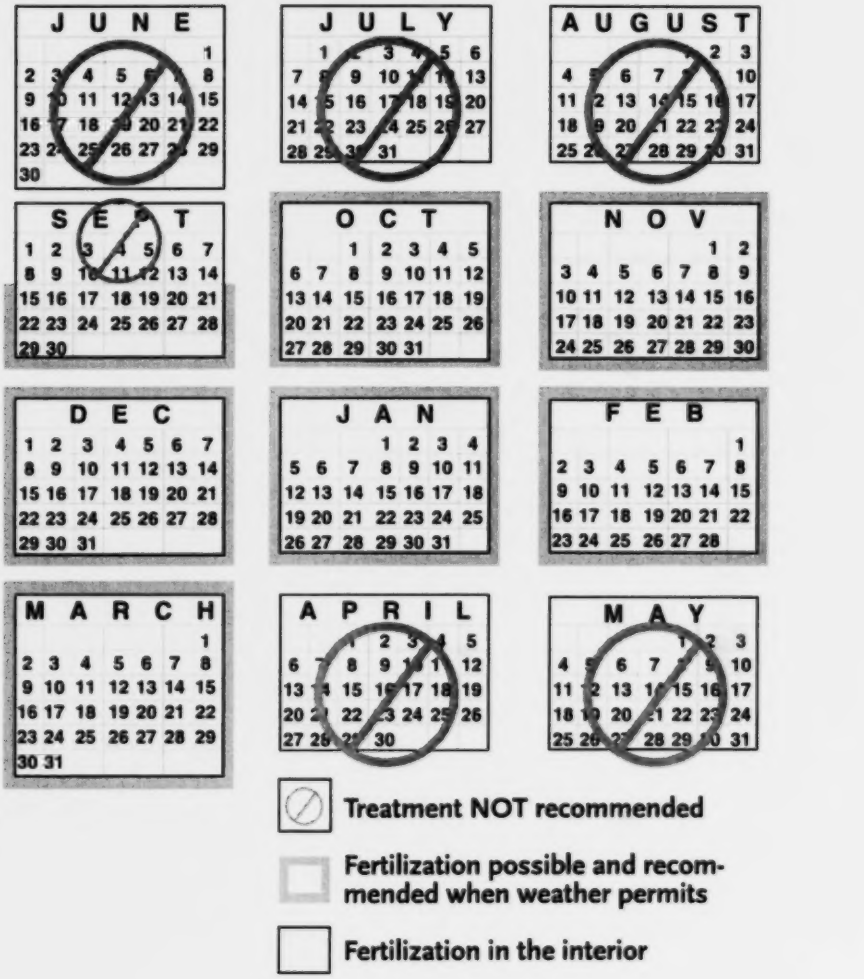


Overhead: Refertilization

Key Points

- The first semicircle represents the total duration and amount of growth response for the initial fertilization. If the second treatment occurs before this response is complete, the area of the shaded area is the potential loss of growth response *but* the elevated growth response is sustained
- Forage may benefit from the excess fertilizer, but this would have to be prescribed accordingly as a desired treatment result

Season of Application



Overhead: Season of Application

Key Points

- Important to distinguish coast and interior application periods
- Best to spread urea in cool and moist conditions during periods of active root growth for best uptake
- Time periods to fertilize:
  - on the coast, from mid-September to mid-March
  - in the interior, from September to mid-November
- Interior fertilization contracts usually begin in the north, with the work moving south as the north receives snow and temperatures in the south cool down
- Fertilization on snow is only desirable if prill will sink into snow (no frozen crust) and slopes are <30%. In general, fertilization on snow is not recommended. A related factor is that the roads are likely to be in unsuitable condition for heavy fertilizer trucks at this time. Additional costs for road maintenance may reduce the fertilization project's overall cost effectiveness.

Monitoring Plan Checklist

- Loading sites cleaned
- Flight paths, flying procedures, radio traffic, fertilizer application
- Weather and flying conditions
- Check perpendicularly to flight lines for even coverage, prescribed overlap and no gaps
- Block boundaries, buffer zones and No Treatment areas
- Monitor the cumulative weight of fertilizer spread

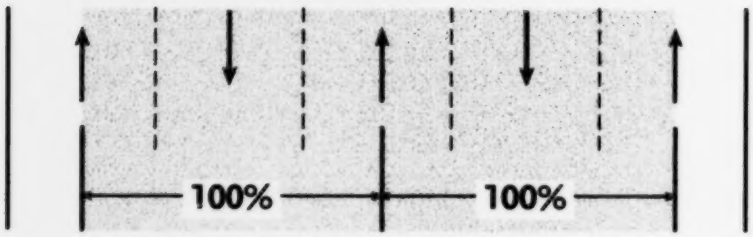
Overhead: Monitoring Plan Checklist

Key Points

- Review overhead with participants – there may be questions or comments based on their experience
- Loading sites must be cleaned at end of day to ensure that livestock and wildlife cannot graze on residual spill piles of fertilizer prill
- Monitor cumulative weight of fertilizer applied by comparing number of flights and amount of fertilizer emptied from the supply trucks or bags

Calibration

- Important to ensure prescribed application rate
- Test run when project begins
- Check periodically
- Contractor should be familiar with calibration and confident with application rate
- Proper application is in contractor's best interest!



* 50% application on each flight line adds up to 100% application when flight lines overlap

Overhead: Calibration

Key Points

- Calibration is based on 100% overlap of application with 50% on edges of blocks where flight lines do not overlap
- Show direction of flight lines on overhead example and clarify how the overlap works
- Overlap helps to ensure even application
- Loading sites must be cleaned at end of day to ensure that livestock and wildlife cannot graze on residual spill piles of fertilizer prill

On-site Documents

- Contingency plan for fertilizer spills
- Material Safety Data Sheet (MSDS) for fertilizer
- Fertilization contract with maps showing buffer areas
- Silviculture Prescription/ Stand Management Prescription

Overhead: On-site Documents

Key Points

- Important to emphasize safety to the participants: safety to humans, livestock, wildlife, water quality
- Everyone working on site should have a copy of the maps so that they are perfectly clear on the application area and the No Treatment buffers
- Clear maps of the application blocks and surrounding areas are particularly important

Contingency Plan

- Name and phone number for contacts in the:
  - Ministry of Health
  - Ministry of Forests
  - Ministry of Environment, Lands and Parks
  - Ministry of Transportation and Highways
  - Regional District
  - RCMP
- Necessary to inform that clean-up is in progress
- Contingency plan available in vehicles

Overhead: Contingency Plan

Key Points

Lesson 10

Monitoring

15 minutes

Objectives

- Discuss the need and differing objectives for establishing growth response monitoring
- Describe the Ministry of Forests monitoring strategy and methodology

Equipment Needs

- Overhead projector
- Lesson 10 transparencies

Method

Lecturette with overheads

Instructions

The main point of this lesson is the need to monitor similar stands to find the trends in response from fertilization. Monitoring does not always need to be concerned with absolute numbers. The type of response – positive or negative – and its duration are important to determine the effectiveness of a fertilizer application and the appropriateness of treating similar stands.

The monitoring of an operational fertilization growth response must first have defined objectives. These can range from simply ensuring that the suspected deficient nutrient has been temporarily corrected, to quantifying, if desired, the actual amount of increased wood volume or change in stand development to shorten the rotation. There is also a relationship between the response pattern to fertilization and the stage of stand development. Therefore, the analysis and sampling program may have to differ for stands of different age, site and number of fertilization treatments.

Three main methods of monitoring are recommended. **Foliar analysis** can be used to assess individual tree response to fertilization. A pre- and post-fertilization sampling scheme of the same dominant and co-dominant trees can be used provided the area surrounding the trees selected is checked for uniform fertilizer application at the time of treatment. Stratification is required with very large blocks of greater than 100 hectares. The purpose of the permanent sample plot approach of the Ministry of

Forests is to build a database for the development of growth and yield equations and tables. Project staff should be encouraged to look at needle weight response and foliar analysis to assess the effectiveness of operational fertilization treatments. Pre- and post-fertilization sampling of preselected trees should be encouraged.

It is important to measure and record the weather conditions before, during and after fertilizer application. The weather may help to explain anomalous results, such as low response rate due to heavy rain immediately after the fertilization treatment. Inspection during application of uniform pattern and within the range of the target application rate should also be completed.

Operational trials are recommended to establish a better base for determining fertilization response. **Increment cores** of fertilized stands will yield historical data on the type and duration of response by diameter growth. Nitrogen-induced deficiencies will also be evident in an increment core if the time of fertilization can be determined on the core. Nutrient deficiencies caused by fertilization will probably also be evident in the stand's condition and vigour. For example, nitrogen-induced boron deficiencies will produce dead leaders and stunted, unacceptable height growth.

Contact with the regional stand tending forester is important for all monitoring. This specialist will be able to advise on the best monitoring programs for the district and stands in which the fertilization program has been conducted. As well, the stand tending forester will be able to link district trends into a provincial scale and provide post-fertilization trends from other regions and districts.

Monitoring Objectives

- **Site selection – Monitoring guidelines**
- **Quality control – Monitoring operations**
- **Response measurement – Monitoring stand behaviour after treatment**
- **Past efforts have focused at the stand level**
- **Monitoring how, and how well, site selection and operations have been conducted is useful to judge effectiveness of fertilization program**

Overhead: Monitoring Objectives

Key Points

- The first three bullets list types of monitoring (of guidelines, operations and post-treatment stand behaviour)
- Monitoring is needed to adjust stand selection guidelines, quality control or other aspects of future fertilization programs to improve the programs' effectiveness

Fertilizer Application Monitoring

Objectives

- Define acceptable accuracy standards to:
  - Monitor contractor performance
  - Document for treatment records
- Aim for +/- 10% accuracy

Estimation of Fertilizer Application Rate

Total amount of fertilizer applied/size of area

- No estimate of variability

Sample traps

- Use only in open areas
- Cumbersome and time consuming
- No information on swath width or overlap
- Fertilizer may bounce out
- Large number of traps required
- Use in control and fertilized plots to compare

Measurement of swath width and overlap on ground

- Quick and easy
- No prill counting or weighing

Overhead: Fertilizer Application

Key Points

- Application rate must be monitored to check contractor performance for contract payment and treatment records
- Can use one or more of these methods
- The 3rd estimation method is best since 1st method (total weight/# of ha) gives no information on variability. Sample traps (2nd method) are often problematic in many respects (prill bounces out, need to anticipate flight line and set up traps before application, need 70 traps/ha for statistical soundness)
- Will need contact with pilot regarding swath length

Growth Response Monitoring

- Install operational plots ("short-term" PSPs)
- Monitoring essential to supplement research but cannot substitute for it
- Appropriate monitoring strategy will depend on treatment objectives
- Confirm and document methodology and responsibilities prior to the fertilization treatment
- Representative control blocks must be established before fertilization
- Establish database in each district to note response trends

Overhead: Growth Response Monitoring

Key Points

- Important to establish trends in each district for different stands – are response trends positive, negative or nil?
- Establishing plots at time of treatment will ensure they are there later if necessary
- Use monitoring to justify future fertilization programs or learn why poor responses are not better
- Actively assess if fertilization is successful
- Important to consult and communicate with regional stand tending forester

Appendix

Forest Fertilization and Management Objectives

Note: Workshop participants are encouraged to explore the information presented in this appendix to further their background knowledge of forest fertilization planning.

The opinions of a person outside of our country can sometimes provide a different and unique perspective of the situation, particularly when that country (Sweden) has significant experience with this forest management tool and its effects. The three postulates of Stig Hagner, Professor of Silviculture and Director of Forestry Operations, Svenska Cellulosa Ab., provide an opportunity to discuss if the conditions are suitable for forest fertilization in BC.

The following is a synopsis of a paper given by Professor Stig Hagner at the March, 1988 Forest Fertilization Workshop entitled "Improving Forest Fertilization Decision-making in British Columbia." His talk gave an overview of Sweden's fertilization experience and role in forest management. He suggested three postulates (prerequisites or fundamental conditions) regarding the basic conditions that forest fertilization must satisfy to be considered a suitable silviculture management treatment. The postulates are:

- The agency benefiting from the increased wood availability should fund its production.
- Forest fertilization should be integrated into an overall plan for long-term utilization of forest resoures, requiring that the agency planning to benefit has long-term security of tenure.
- Forest fertilization can be justified on economic grounds if, for forest owners who sell timber, the increased value of the selling price of the wood is greater than the cost to produce it. For forest owners also operating wood-processing facilities, the forest fertilization can be justified if it improves the industry's raw material supply position at a cost that permits profitable production, or allows for obtaining harvested timber from less expensive sources.

Think about these three postulates and put them in the perspective of British Columbia and its current state of forest management.

- Do you agree or disagree with Stig Hagner?
- With the high level of privately owned forest in Sweden (by small land owners and by the forest industry), how would a fertilization program in Sweden differ from that in British Columbia?

- What are the limiting factors to an expanded forest fertilization program in BC?
- How could BC's factors be modified to allow for an expanded program and the resulting benefits?
- In light of recent land use plans and zoning in BC through higher level plans, how could fertilization be used more beneficially?

Foliar Analysis

Interpretation and Diagnosis Exercises

Consider each of the following scenarios and make interpretations on the possibility of the stand being affected by nutrient deficiencies. Identify possible deficiencies and explain which factor may be contributing to the occurrence of the foliar nutrient levels found.

Scenario 1

A young (7 to 10 year old) hemlock plantation in the Campbell River forest district is showing obvious signs of "checked height growth." The initial height growth following burning and plantation establishment was good (40–60 cm/year) and has now declined to less than 15 cm per year. The trees are growing on an old cedar-hemlock site with a surface organic horizon approximately 55 cm thick of decaying wood. Soil samples of this organic soil type (Folisolic Humoferric Podzol) show high C:N ratio, low mineralization rates and high probability of immobilization. The site has a fresh to moist SMR and poor SNR. Annual rainfall is approximately 2600 mm/year.

Foliage samples were collected as a composite sample of 15 trees during the dormant season of 1987. The following foliar nutrient levels were found:

	%		ppm
N	0.61	SO_4-S	214
P	0.13	Cu	4.3
K	0.78	Zn	26
Ca	0.52	Mn	957
Mg	0.08	Active Fe	66
S	0.07	B	18

What are the site factors likely contributing to the poor growth performance of this plantation? Is nitrogen fertilization likely to result in improved growth performance? What other nutrient(s) would you prescribe and would you expect to get a long-term growth response?

Answer:

Scenario 2

A 32 year old white spruce stand is growing in the Bowron River area of the Prince George Forest District. The site is very productive, the actual soil moisture regime is fresh to moist, and the actual soil nutrient regime is medium to rich. The understory vegetation is in the *Gymnocarpium–Oplopanax* plant association. The site is located at the toe of a long slope with the forest classified as a Mormoder and the mineral soil as an Orthic Eutric Brunisol approximately 1.5 m deep and moderately well drained. The annual height increment is 75–100 cm.

	%		ppm
N	1.22	SO_4-S	55
P	0.145	Cu	2.3
K	0.62	Zn	16
Ca	0.29	Mn	125
Mg	0.085	Active Fe	44
S	0.116	B	9

Is this stand likely to respond to fertilization? What nutrients are likely to be most deficient, if any? Are any site or stand factors important when considering the nutrient status of this stand?

Answer:

Scenario 3

A 22 year old lodgepole pine stand is located in the Anahim Lake area of the Chilcotin Plateau. The stand has developed on an outwash terrace, and the parent material mineralogy is acid igneous, primarily granodiorites and quartz-diorites. The forest floor is a thin Hemimor while the mineral soil is a well-drained coarse-textured gravelly loamy-sand. Annual precipitation is approximately 740 mm with a prolonged summer drought. This stand has been already spaced and fertilized with 225 kg N/ha as urea. These are the post-treatment foliar analysis results.

	%		ppm
N	1.29	SO_4-S	235
P	0.182	Cu	4.2
K	0.57	Zn	13
Ca	0.40	Mn	565
Mg	0.115	Active Fe	34
S	0.116	B	5.2

Is this stand likely to have responded to the nitrogen fertilization? If not, what factors are likely to have contributed to the lack of response? Are any visual symptoms of nutrient deficiency likely to be present?

Answer:

Example of Calculating Fertilizer Application Rate

The most common application rate for nitrogen on the coast is 200–225 kg N/ha and slightly less for the interior at 175–200 kg N/ha. Note that the *application rate* is properly stated in terms of an amount of nutrient element applied. The actual amount of fertilizer material (prill) applied depends on the concentration of the element in the material.

For example, the fertilizer material – urea [$(NH_2)_2CO$] – is only 46% nitrogen by weight. Therefore, the amount of urea to apply to achieve the target rate of application of 200 kg N/ha is:

$$\frac{200 \text{ kg N/ha}}{0.46 \text{ N}} = 435 \text{ kg/ha}$$

For the interior, where ammonium sulphate [$(NH_4)_2SO_4$] may be used, the concentration of nitrogen is only 21% by weight. The amount to apply to achieve the target rate of application of 170 kg N/ha is:

$$\frac{170 \text{ kg N/ha}}{0.21 \text{ N}} = 810 \text{ kg/ha}$$

A blend of forest grade urea plus forest grade ammonium sulphate results in a target application rate of approximately 520 kg/ha. The percentage of elemental concentration can be calculated from the chemical formula using the atomic weights for each individual element or more easily determined from conversion tables. An example of a table for nitrogen (N), phosphorus (P) and potassium (K) is provided below. There are two common ways for fertilizers to be named – the fertilizer material name or the grade. For example, urea is the material name for a nitrogen fertilizer with a grade of 46-0-0, that is to say 46% N, 0% P_2O_5 (phosphate) and 0% K_2O (potash).

All fertilizers can be referred to by either their material name or grade. Single nutrient fertilizers are called "materials" or "simple" fertilizers. Multinutrient fertilizers are called "mixed fertilizers." Multinutrient fertilizers are given a numerical designation consisting of three numbers. This three-number designation is called a "grade." The numbers are the content of nitrogen, phosphate and potash in terms of percent by weight. A zero designation in a grade indicates that that particular nutrient is not included in the fertilizer.

Conversion tables are available to calculate the actual amount of an element source provided in a simple or mixed fertilizer.

Conversion Table

Fertilizer material	Grade	Element source	To convert from (multiple by)	
(A)		(B)	A → B	B → A
urea $CO(NH_2)_2$	46-0-0	N	0.4665	2.1437
ammonium nitrate NH_4NO_3	35-0-0	N	0.3500	2.8557
ammonium sulphate $(NH_4)_2SO_4$	21-0-0	N	0.2120	4.7169
triple superphosphate $Ca(H_2PO_4)_2$	0-45-0	P	0.1962	5.0968
superphosphate	0-20-0	P	0.0873	11.454
potassium chloride (KCl)	0-0-63	K	0.5229	1.9124
ammonium sulphate $(NH_4)_2SO_4$	21-0-0-24S	S	0.2426	4.1220
granular borate	0-0-0-14B	B	0.1430	7
borax $Na_2B_4O_7 \cdot H_2O$	0-0-0-11B	B	0.1134	8.8129

Note that both the P and K in the grade are not for percentage of these elements but for percentage by weight of phosphate (phosphorus pentoxide) and potash (potassium oxide), which are only in part composed of these elements.

Exercise to Determine Fertilizer Application Rates

Question #1

Show that it is more costly to apply ammonium nitrate fertilizer than it is to use urea. Assume that the growth response to a single application of 200 kg N/ha is the same for either form of N and that the cost per metric ton of material is $250/ha.

Answer:

Question #2

Show that the operational mix of 58% urea and 42% ammonium sulphate produces the blended fertilizer of 35-0-0-10S that is 35% N by weight. What is the application rate to achieve 175 kg N/ha + 50 kg S/ha?

Answer:

Question #3

For an operational trial, you have decided to use a blended fertilizer to correct the specific nutritional deficiencies discovered through screening trials. Your tree nutrition specialist recommends the application of 226 kg N/ha, 135 kg P/ha and 48 kg S/ha to address this forest nutrient problem.

What would be the combination of fertilizers to formulate such a blend, assuming it is best to use only urea (U), ammonium sulphate (AS) and triple superphosphate (TSP)? What would be the application rate of this mix?

Answer:

Checking Application Rate by Determining Swath Length and Drop Duration

Question #4

The coast version is in **bold** (interior version in parenthesis). The application of forest fertilizer by helicopter is frequently done using a Bell 205 equipped with a 1500 kg capacity spreader or hopper. The swath width has been determined at earlier calibration applications to be 60 m. If the target fertilizer material application rate with **urea** (urea + ammonium sulphate mix) is **450** kg/ha (510 kg/ha) and the swath overlap is for triple coverage, what is the estimated distance of each swath or run with the helicopter traveling at a ground speed of 90 km per hour? How long in minutes or seconds will it take to empty the spreader?

Answer: